SECTION II—CRYSTAL UNITS

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SECTION II—CRYSTAL UNITS

INTRODUCTION

2-1. Section II contains all available descriptions of crystal units now being used in USAF equipments. The crystal units are divided into two groups, as defined in subparagraphs a and b below. Technical data charts present a convenient summary of the crystal units in each group, and following each of the charts are data sheets giving more complete information about the individual units. At the end of Section II is a digest of Military Standard terms, tests, and procedures applicable to crystal units which meet military specifications.

a. Group I includes those Military Standard crystal units that are recommended for use in equipments of new design. These are the crystal units assigned Joint Army-Navy-Air Force type number CR-XX/U, where XX is a two-digit number equal to 15 or higher. Except in the event of unusual or special requirements, the design engineer of crystal-controlled circuits for military equipment should consider only those crystal units in Group I.

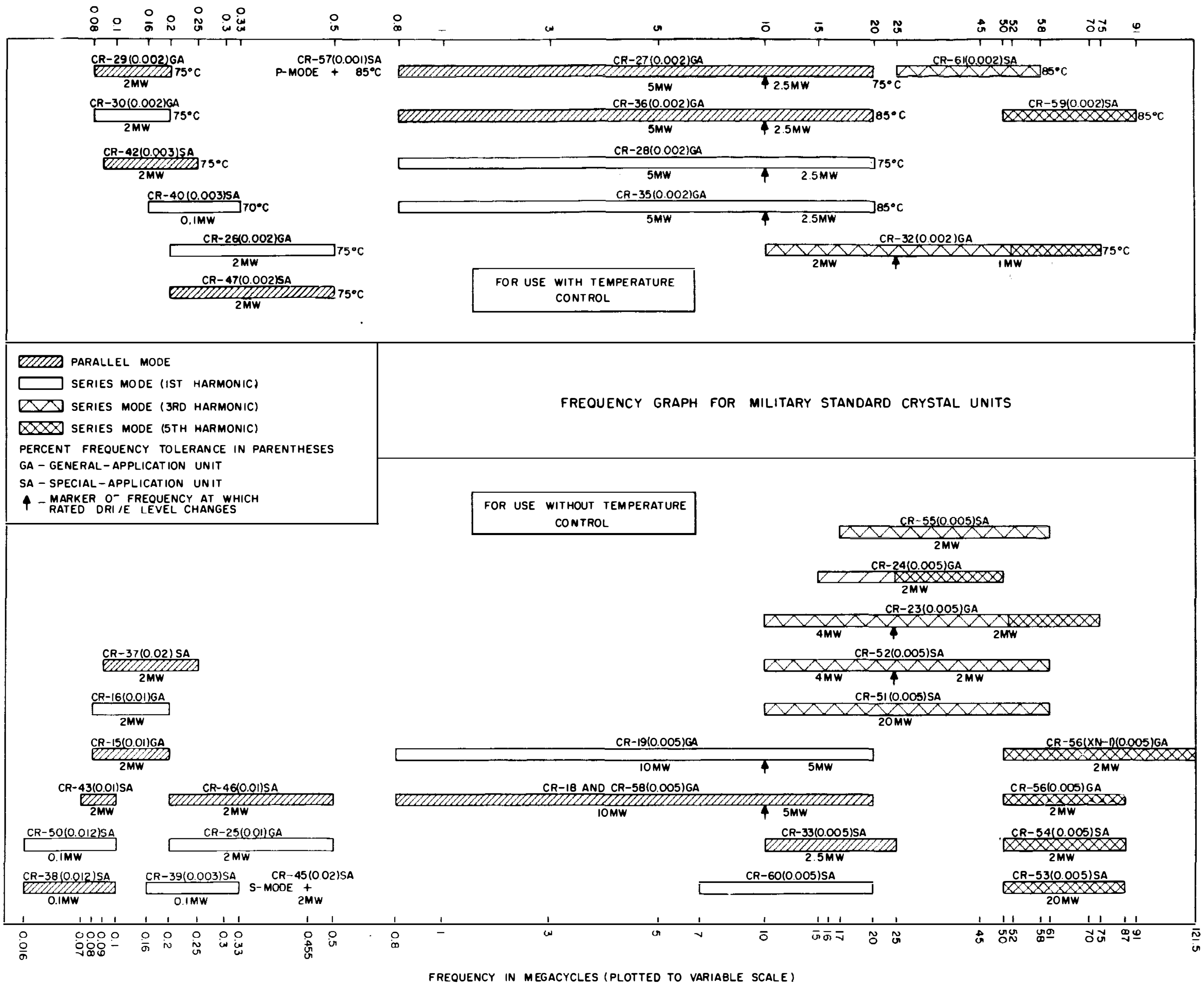
b. Group II includes the older types of crystal units which are still widely used in current models of USAF radio equipments, but which are not recommended for use in military equipments of new design. These crystal units are arranged in the order of their USAF stock numbers, which numbers are the same as the Signal Corps stock numbers except for the addition of the prefix "2100-," which serves to identify the item as belonging to the USAF 16-F stock class. The information concerning the Group-II crystal units is included primarily for the benefit of the crystal specialist or field engineer in the military. As a reference source of crystal units and available frequencies, it may also prove helpful to design and research engineers.

GROUP I
RECOMMENDED MILITARY STANDARD CRYSTAL UNITS

The crystal units included in Group I are those conforming to Military Standards and which are recommended for use in armed-services equipment of new design. These units are further classified as belonging to one of two categories and are specified in Military Specification MIL-C-3098( ) —the latest issue or amendment in effect, as applicable.

Category 1 is composed of those crystal units which are available in production from two or more sources.

Category 2 is composed of those crystal units which are available in limited production and possibly from only one source. The crystal units in this category also may be individual types which are in the process of being replaced by units of new design, or which, at a later date, may be placed in Category 1 by virtue of increased utility and availability.


CR-29(0.002)GA 75°C 2MW
CR-30(0.002)GA 75°C 2MW
CR-42(0.003)SA 75°C 2MW
CR-40(0.003)SA 70°C 0.1MW
CR-26(0.002)GA 75°C 2MW
CR-47(0.002)SA 75°C 2MW
CR-57(0.001)SA P-MODE + 85°C
CR-27(0.002)GA 5MW 2.5MW 75°C
CR-36(0.002)GA 85°C 5MW 2.5MW
CR-28(0.002)GA 75°C 5MW 2.5MW
CR-35(0.002)GA 85°C 5MW 2.5MW
CR-61(0.002)SA 85°C
CR-59(0.002)SA 85°C
CR-32(0.002)GA 75°C 2MW 1MW
FOR USE WITH TEMPERATURE CONTROL
PARALLEL MODE
SERIES MODE (1ST HARMONIC)
SERIES MODE (3RD HARMONIC)
SERIES MODE (5TH HARMONIC)
PERCENT FREQUENCY TOLERANCE IN PARENTHESES
GA - GENERAL-APPLICATION UNIT
SA - SPECIAL-APPLICATION UNIT
MARKER OF FREQUENCY AT WHICH RATED DRIVE LEVEL CHANGES
FREQUENCY GRAPH FOR MILITARY STANDARD CRYSTAL UNITS
FOR USE WITHOUT TEMPERATURE CONTROL
CR-55(0.005)SA 2MW
CR-24(0.005)GA 2MW
CR-23(0.005)GA 4MW 2MW
CR-52(0.005)SA 4MW 2MW
CR-51(0.005)SA 20MW
CR-37(0.02) SA 2MW
CR-16(0.01)GA 2MW
CR-15(0.01)GA 2MW
CR-43(0.01)SA 2MW
CR-46(0.01)SA 2MW
CR-50(0.012)SA 0.1MW
CR-25(0.01)GA 2MW
CR-38(0.012)SA 0.1MW
CR-39(0.003)SA 0.1MW
CR-45(0.02)SA S-MODE + 2MW
CR-19(0.005)GA 10MW 5MW
CR-18 AND CR-58(0.005)GA 10MW 5MW
CR-33(0.005)SA 2.5MW
CR-60(0.005)SA
CR-56(XN-1)(0.005)GA 2MW
CR-56(0.005)GA 2MW
CR-54(0.005)SA 2MW
CR-53(0.005)SA 20MW
0.016 0.07 0.08 0.09 0.1 0.16 0.2 0.25 0.3 0.33 0.455 0.5 0.8 1 3 5 7 10 15 16 17 20 25 45 50 52 58 61 70 75 87 91 121.5
FREQUENCY IN MEGACYCLES (PLOTTED TO VARIABLE SCALE)

TECHNICAL DATA CHART FOR GROUP-1 MILITARY STANDARD CRYSTAL UNITS

Frequency Range (kc)	*Frequency Tolerance (±%)*	*Operating Temperature Range (°C)*	*Resonance*	*Load Capacitance (mmf)*	*Holder Type*	*Availability Category*[a]	*Crystal Unit Type*
16-100	0.012	−40 to +70	parallel	20 ±0.5	HC-13/U	2	CR-38/U
16-100	0.012	−40 to +70	series	…	HC-13/U	2	CR-50/U
80.860 (70-100)	0.010	−30 to +75	parallel	45 ±1.0	HC-16/U	2	CR-43/U
[illegible]-200	0.01[illegible]	−40 to +70	parallel	32 ±0.5	HC-5/U	1	CR-15/U
80-200	0.016	−40 to +70	series	…	HC-5/U	1	CR-16/U
80-200	0.002[b]	75 ±5	parallel	32 ±0.5	HC-5/U	1	CR-29/U
80-200	0.002[b]	75 ±5	series	…	HC-5/U	1	CR-30/U
90-250	0.020	−40 to +70	parallel	20 ±0.5	HC-13/U	2	CR-37/U
90-250	0.003	75 ±5	parallel	32 ±0.5	HC-13/U	2	CR-42/U
160-330	0.003	−55 to +75	series	[c]	HC-15/U	2	CR-39/U
160-330	0.003[b]	70 ±5	series	[c]	HC-15/U	2	CR-40/U
200-500	0.010	−40 to +70	series	…	HC-6/U	1	CR-25/U
200-500	0.002[b]	75 ±5	series	…	HC-6/U	1	CR-26/U
200-500	0.010	−40 to +70	parallel	20 ±0.5	HC-6/U	2	CR-46/U
200-500	0.002[b]	75 ±5	parallel	20 ±0.5	HC-6/U	2	CR-47/U
455	0.020	−40 to +70	series	…	HC-6/U	2	CR-45/U
500	0.001	85 ±5	parallel	32 ±0.5	HC-6/U	1	CR-57/U
800-3000	0.0075	−55 to +90	parallel	32 ±0.5	HC-6/U	2	CR-48/U[d]
800-3000	0.0075	−55 to +90	parallel	32 ±0.5	HC-6/U	2	CR-49/U[d]
800-15,000	0.002[b]	75 ±5	parallel	32 ±0.5	HC-6/U	1	CR-27/U
800-20,000	0.002[b]	85 ±5	parallel	32 ±0.5	HC-6/U	1	CR-36/U

Frequency Range (kc)	*Frequency Tolerance (±%)*	*Operating Temperature Range (°C)*	*Resonance*	*Load Capacitance (mmf)*	*Holder Type*	*Availability Category*[a]	*Crystal Unit Type*
800-20,000	0.005	−55 to +90	parallel	32 ±0.5	HC-6/U	1	CR-18/U
800-20,000	0.005	−55 to +90	parallel	32 ±0.5	HC-17/U	1	CR-58/U
800-20,000	0.005	−55 to +90	series	......	HC-6/U	1	CR-19/U
800-20,000	0.002[b]	75 ±5	series	......	HC-6/U	1	CR-28/U
800-20,000	0.002[b]	85 ±5	series	......	HC-6/U	1	CR-35/U
7000-20,000	0.005	−55 to +105	series	......	HC-18/U	1	CR-60/U
10,000-25,000	0.005	−55 to +90	parallel	32 ±0.5	HC-6/U	1	CR-33/U
10,000-61,000	0.005	−55 to +90	series	......	HC-6/U	1	CR-51/U
10,000-61,000	0.005	−55 to +90	series	......	HC-6/U	1	CR-52/U
10,000-75,000	0.005	−55 to +90	series	......	HC-6/U	2	CR-23/U[e]
10,000-75,000	0.002[b]	75 ±5	series	......	HC-6/U	1	CR-32/U
15,000-20,000	0.002[b]	85 ±5	parallel	32 ±0.5	HC-6/U	2	CR-44/U[f]
15,000-50,000	0.005	−55 to +90	series	......	HC-10/U	1	CR-24/U
17,000-61,000	0.005	−55 to +105	series	......	HC-18/U	1	CR-55/U
25,000-58,000	0.002	85 ±5	series	......	HC-18/U	1	CR-61/U
50,000-87,000	0.005	−55 to +90	series	......	HC-6/U	1	CR-53/U
50,000-87,000	0.005	−55 to +90	series	......	HC-6/U	1	CR-54/U
50,000-87,000	0.005	−55 to +105	series	......	HC-18/U	1	CR-56/U
50,000-91,000	0.002	85 ±5	series	......	HC-18/U	1	CR-59/U

[a] See explanation of categories in paragraphs immediately preceding this chart.

[b] In addition, the crystal unit shall not deviate more than 0.0005% (0.0003% for CR-57/U) from the frequency value measured at the midpoint of the operating temperature range, when measured over the entire operating temperature range.

[c] The permitted value of load capacitance for this crystal unit depends upon the frequency at which the unit is operated.

[d] For replacement use CR-18/U.

[e] For replacement use CR-52/U or CR-54/U whichever is applicable.

[f] For replacement use CR-36/U.

CRYSTAL UNIT CR-15/U (LF)

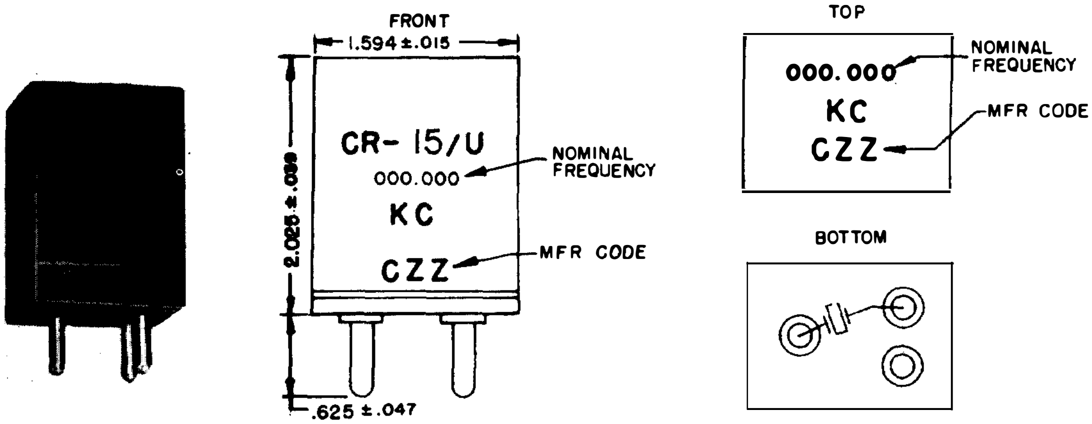


Figure 2-1. Crystal Unit CR-15/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a plastic holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits which must maintain good frequency stability in the absence of oven control, even when exposed to wide variations in temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 80 to 199.999 kc

Nominal Frequency Tolerance: ±0.01% at all temperatures within operating range

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: —40° to +70°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range

Resonance: Parallel

Load Capacitance: 32 ±0.5 $\mu\mu$f

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level: 2 mw

Maximum Pin-to-Pin Capacitance: Not specified

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
80 to 119.999	10,000
120 to 159.999	8000
160 to 199.999	6000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, modified transitron, Miller, modified Butler

MOUNTING DATA

Crystal Holder: HC-5/U or HC-21/U

Method of Mounting Crystal: Wire-mounted in plastic holder

Dimensions and Marking: See figure 2-1(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X515-frequency in kc

Status: Standard (Category 1)

Date of Status: 9 October 1950

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: Use of this crystal is discouraged by some manufacturers because, in their opinion, the specified holder (HC-5/U) suffers these important disadvantages: The holder is not hermetically sealed (although a metal hermetically-sealed version will be used in procurement of further models); it has poor form factor; and it uses an unorthodox base which requires a special socket.

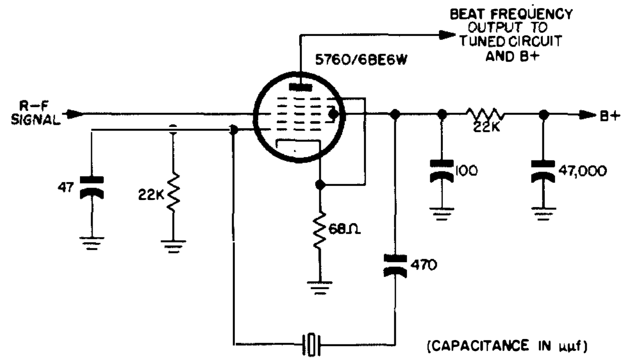


Figure 2-2. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-15/U

Equipment Used In: Radio Receiver R-277/APN-70

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

Aging Test: Not required

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
80 to 119.999	1000
120 to 159.999	800
160 to 199.999	700

**CRYSTAL UNIT CR-16/U
(LF)**

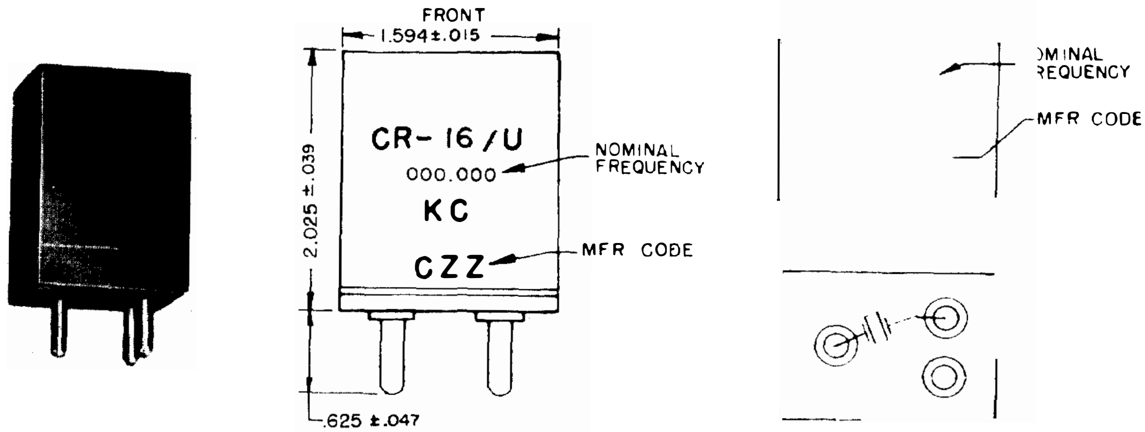


Figure 2-3. Crystal Unit CR-16/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a plastic holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits which must maintain good frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 80 to 199.999 kc
Nominal Frequency Tolerance: ±0.01% at all temperatures within operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range.
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance: 3000 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, transitron, transformer-coupled, modified Butler, and Meacham-bridge

MOUNTING DATA

Crystal Holder: HC-5/U or HC-21/U
Method of Mounting Crystal: Wire-mounted in plastic holder
Dimensions and Marking: See figure 2-3(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X516-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Use of this crystal unit is discouraged by some manufacturers because, in their opinion, the specified holder (HC-5/U) suffers these important disadvantages: The holder is not hermetically sealed (although a metal hermetically-sealed version will be used in procurement of future models); it has a poor form factor; and it uses an unorthodox base which requires a special socket.
Equipment Used In:
Signal Generator SG-34(XA)/UP—see figure 1-175 (K)

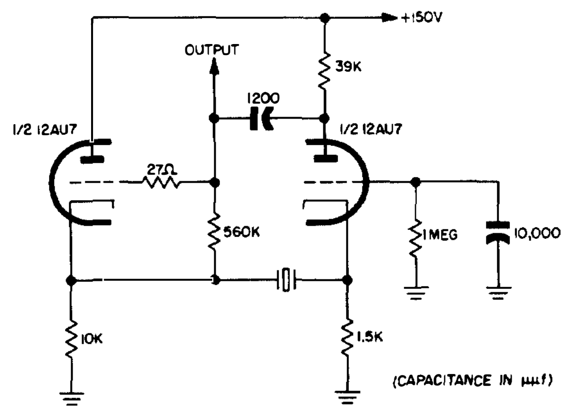


Figure 2-4. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-16/U

Signal Generator SG-34/GPM-15—see figure 1-175 (K)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

Aging Test: Not required

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
80 to 119.999	1000
120 to 159.999	800
160 to 199.999	700

CRYSTAL UNIT CR-18/U (MF—HF)

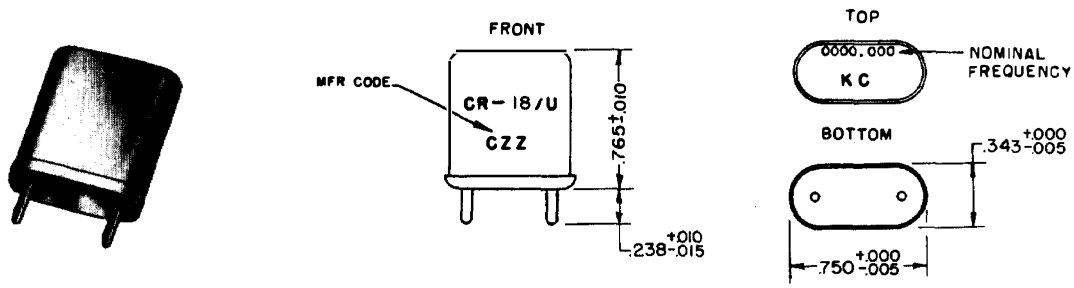


Figure 2-5. Crystal Unit CR-18/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc

Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: −55° to +90°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range

Resonance: Parallel

Load Capacitance: 32 ±0.5 mmf

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level:
800 to 9,999.999 kc—10 mw
10,000 to 20,000 kc—5 mw

Maximum Pin-to-Pin Capacitance: 7.0 mmf

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	320
2500 to 2,999.999	500
3000 to 3,749.999	175
3750 to 4,749.999	120
4750 to 5,999.999	75
6000 to 7,499.999	50
7500 to 9,999.999	35
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -118, -115.

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-6/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-5(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

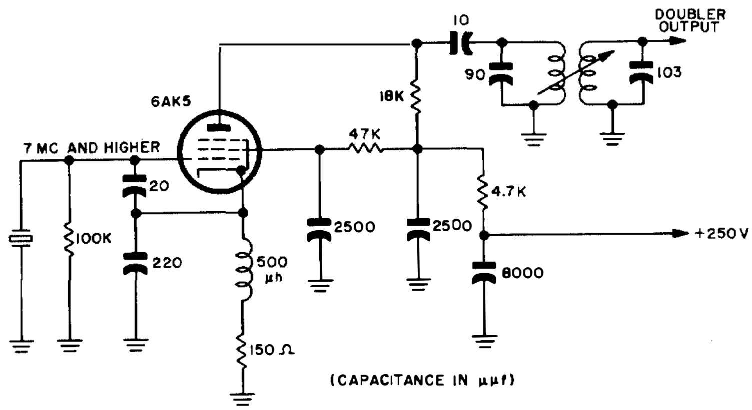


Figure 2-6. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-18/U

LOGISTICAL DATA

USAF Stock No.: 2100-2X518-freqcency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Specification requirements become increasingly difficult to meet at the lower frequencies in manufacturing this unit.
Equipment Used In:
- Receiver-Transmitter RT-173/ARC-33—see figures 1-135 (L), (M)
- Receiver-Transmitter RT-178/ARC-27—see figures 1-135 (R), (V), (W)
- Receiver-Transmitter RT-XA-101/ARC-22—see figure 1-135 (Y)
- Signal Generator SG-13/ARN — see figures 1-135 (Z), -137 (V)
- Frequency Meter TS-186 (B/C)/UP—see figure 1-137 (G)
- Radio Receiver R-540/ARN-14C — see figure 1-137 (N)
- Radio Set AN/ARC-34 (XA-1)—see figures 1-137 (O), (T)
- Radio Receiver R-322/ARN-18 — see figure 1-137 (U)
- R-F Signal Generator Set AN/URM-25C—see figure 1-138 (D)
- Radio Receiver R-277 (XA-A)/APN-70—see figure 1-138 (E)
- Radio Receiver R-252( )/ARN-14 (14 crystals)
- Signal Generator SG-1/ARN (2 crystals)
- Radio Set AN/ART-13B (20 crystals)
- Radio Receiver R-470/ARN-19 (10 crystals)
- Radio Set AN/ARN-22 (12 crystals)
- Radio Set AN/ANT-27
- Radio Set AN/URT-( )
- Radio Set AN/MRC-20 (12 crystals)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955
Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.
Reference Standard Test Set:
Crystal Impedance Meter TS-330/TSM—800 to 14,999.999 kc
Crystal Impedance Meter TS-683/TSM—15,000 to 20,000 kc
Electrical Connection of Holder:
Holder grounded
Method of Measuring Frequency and Effective Resonance Resistance: A.
Drive Adjustment Procedure:
800 to 14,999.999 kc: MS90167 (see paragraph 2-60 and MIL-C-3098B)
15,000 to 20,000 kc: MS90168 (see paragraph 2-62 and MIL-C-3098B)
Shock and Vibration Test:
Permitted change in frequency:
±0.001% for units below 2000 kc
±0.0005% for units of 2000 kc and above
Permitted change in resonance (effective) resistance: Wire-mounted—±15% or 2 ohms, whichever is greater.
Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-19/U
(MF—HF)

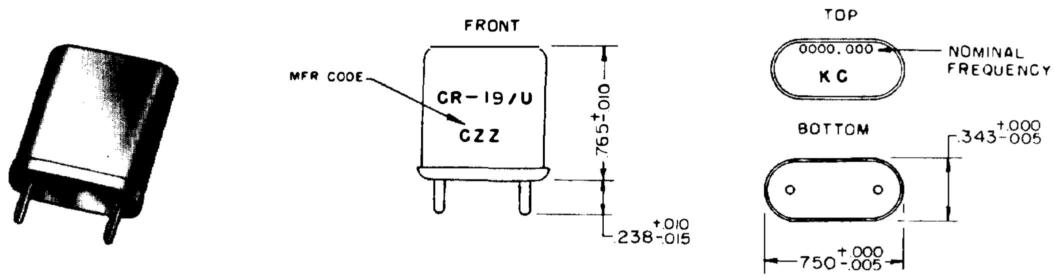


Figure 2-7. Crystal Unit CR-19/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits which must maintain above average frequency stability in the absence of oven control, even when exposed to wide variation of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc

Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: −55° to +90°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range

Resonance: Series

Load Capacitance: 7.0 μμf

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level:
800 to 9,999.999 kc—10 mw
10,000 to 20,000 kc—5 mw

Maximum Pin-to-Pin Capacitance: Not specified

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	800
1000 to 1,249.999	500
1250 to 1,499.999	400
1500 to 1,749.999	350
1750 to 1,999.999	300
2000 to 2,249.999	250
2250 to 3,749.999	150
3750 to 4,999.999	100
5000 to 6,999.999	50
7000 to 9,999.999	30
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-49, figures 1-49, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, transitron, modified Colpitts

MOUNTING DATA

Crystal Holder: HC-6/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-7 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

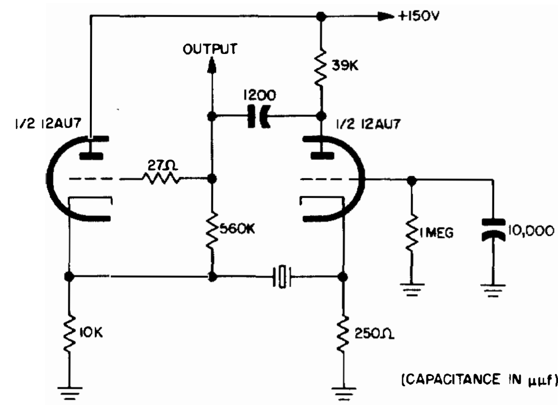


Figure 2-8. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-19/U

LOGISTICAL DATA

USAF Stock No.: 2100-2X519-frequency in kc

Status: Standard (Category 1)

Date of Status: 9 October 1950

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: None

Equipment Used In:
- Signal Generator SG-34(XA)/UP—see figure 1-175 (K)
- Signal Generator SG-34/GPM-15—see figure 1-175 (K)
- Radio Receiver R-277/APN-70 (4 crystals)
- Radio Transmitter T-263/MRN-8 (20 crystals)
- Radio Transmitting Set AN/MRN-7 (39 crystals)
- Radio Set AN/MRC-20; Guard Receiver

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50

Reference Standard Test Set:
- Crystal Impedance Meter TS-330/TSM—800 to 14,999.999 kc
- Crystal Impedance Meter TS-683/TSM—15,000 to 20,000 kc

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure:
- *800 to 14,999.999 kc:* MS90167 (see paragraph 2-60 and MIL-C-3098B)
- *15,000 to 20,000 kc:* MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency:
- ±0.0005% for units of 2000 kc and above
- ±0.001% for units below 2000 kc

Permitted change in effective resonance resistance: Wire-mounted—±15% or 2 ohms, whichever is greater.

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-23/U (HF—VHF)

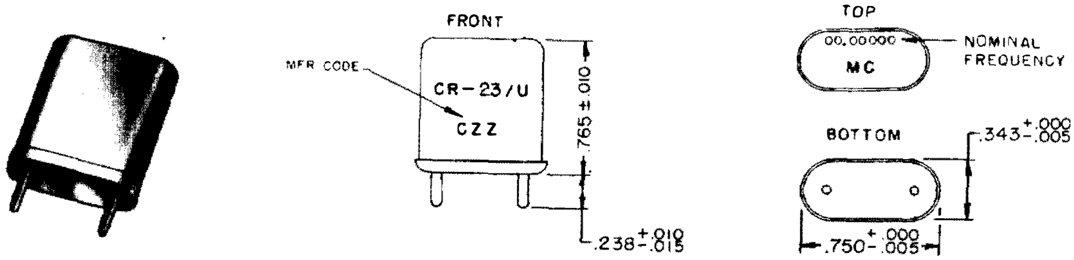


Figure 2-9. Crystal Unit CR-23/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the third or fifth mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high-to-very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 10 to 75 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration:

Overtone	*Frequency (mc)*
Third	10 to 52
Fifth	52.000001 to 75

Maximum Drive Level:
10 to 24.999999 mc (4 mw)
25 to 75 (2 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf

Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
10 to 14.99999	60
15 to 52	40
52.000001 to 75	60

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figure 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-9 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X523-frequency in mc
Status: Standard (Category 2)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Difficult to manufacture to all specification requirements over the entire upper and lower range.

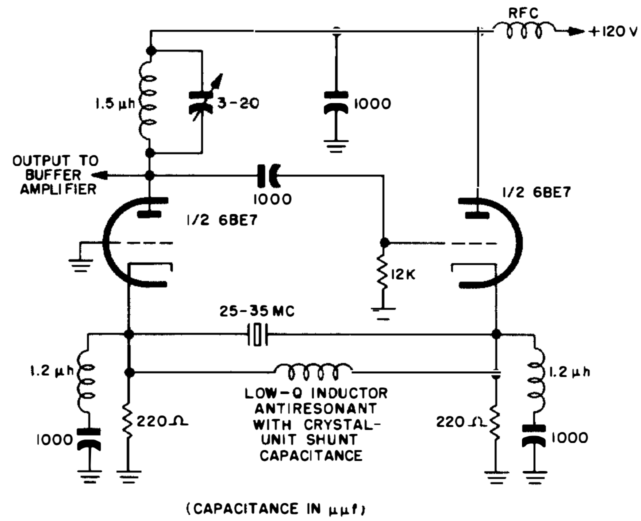


Figure 2-10. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-23/U

Equipment Used In:
- Receiver-Transmitter RT-178/ARC-27—see figures 1-175 (B), (C)
- Radio Receiver R-252A/ARN-14—see figure 1-175 (F)
- Radio Receiver R-540/ARN-14C—see figure 1-175 (H)
- Radio Set AN/ARN-21 (XN-2)—see figure 1-175 (J)
- Signal Generator SG-13/ARN—see figure 1-175 (L)
- Radio Receiver R-470/ARN-19 (14 crystals)
- Radio Set AN/URC-10
- Radio Transmitting Set AN/URT-( )
- Radio Set AN/APX-19 (2 crystals)
- Radio Set AN/GRC-30 (3 crystals)
- Radio Set AN/PRC-14 (6 crystals)
- Radio Set AN/MRC-30, Guard Receiver

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency:
±0.001% for units below 2000 kc
±0.0005% for units of 2000 kc and above
Permitted change in effective resonance resistance: Wire-mounted—±15% or 2 ohms, whichever is greater.

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-24/U
(HF—VHF)

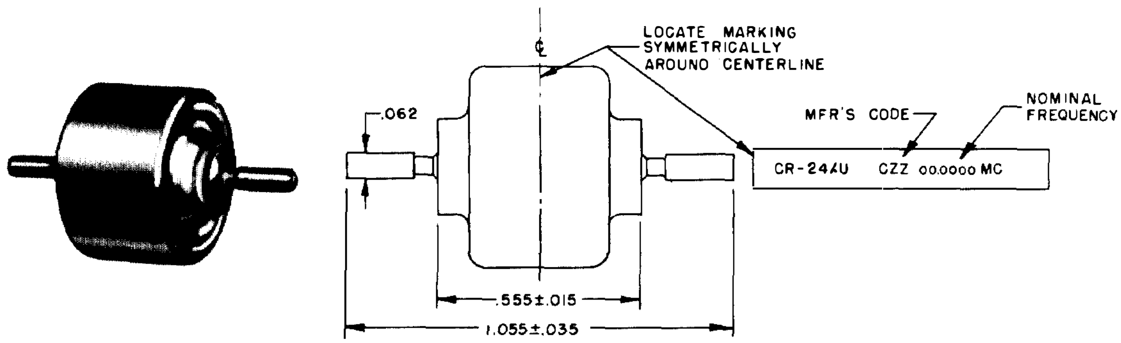


Figure 2-11. Crystal Unit CR-24/U

FUNCTIONAL DESCRIPTION

Pressure-mounted, or metal-plated quartz plate wire-mounted in a metal holder designed to operate on the third or fifth mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high-to-very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variation of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 15 to 50 mc

Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range.

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: —55° to +90°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range.

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration:

Overtone	*Frequency (mc)*
Third	15 to 24.999999
Fifth	25 to 50

Maximum Drive Level: 2 mw

Maximum Pin-to-Pin Capacitance: 7.0 μμf

Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
15 to 24.999999	50
25 to 50	75

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-10/U

Method of Mounting Crystal: Pressure-mounted or wire-mounted in metal holder

Dimensions and Marking: See figure 2-11(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X524-frequency in mc

Status: Standard (Category 1)

Date of Status: 9 October 1950

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: None

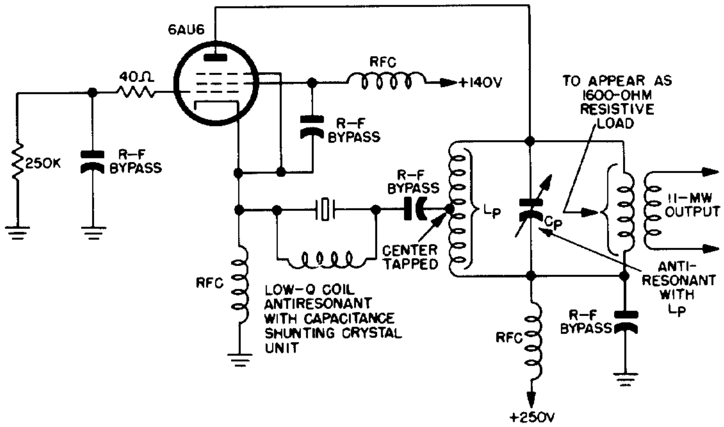


Figure 2-12. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-24/U

Equipment Used In:
- Radio Receiver R-266/URR-13 — see figur- 1-175 (A)
- Receiver-Transmitter RT-159A/URC-4—see figure 1-177 (D)
- Radio Receiver R-122/ARN-12
- Marker Beacon Set AN/ARN-32

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM or ZM-2/U

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.002%
Permitted change in effective resonance resistance: Shall not exceed maximum effective resistance

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-25/U
(LF—MF)

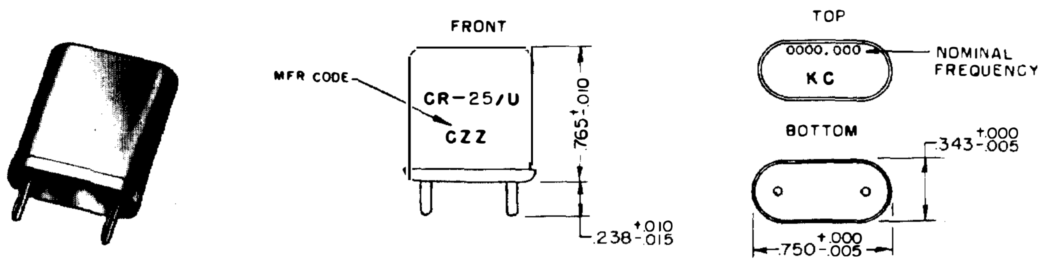


Figure 2-13. Crystal Unit CR-25/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element in circuits which must maintain good frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 200 to 500 kc
Nominal Frequency Tolerance: ±0.01% at all temperatures within operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Minimum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
200 to 249.999	3000
250 to 299.999	4000
300 to 399.999	5000
400 to 449.999	7500
450 to 500	10,000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, transitron, Meacham-bridge, modified Colpitts, modified Butler

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-13 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X525-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Certain waivers from specification are required by some manufacturers before they will produce this unit.
Equipment Used In:
Radio Receiver R-277/APN-70 — see figure 1-138(E) (Not a series-mode circuit as shown)

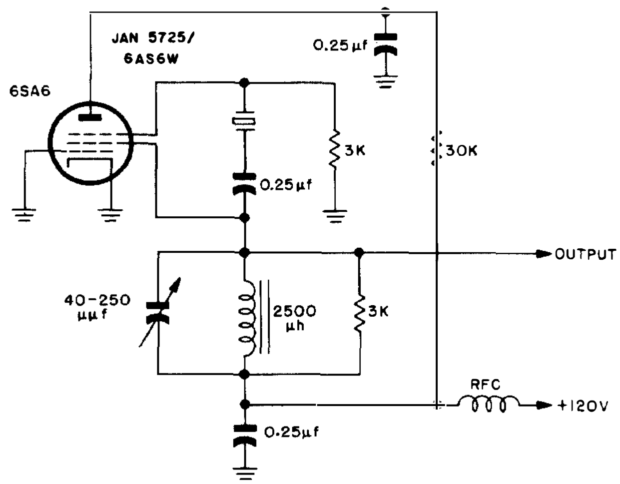


Figure 2-14. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-25/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

Aging Test: Not required

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
200 to 249.999	700
250 to 319.999	500
320 to 369.999	400
370 to 434.999	300
435 to 500	250

CRYSTAL UNIT CR-26/U
(LF—MF)

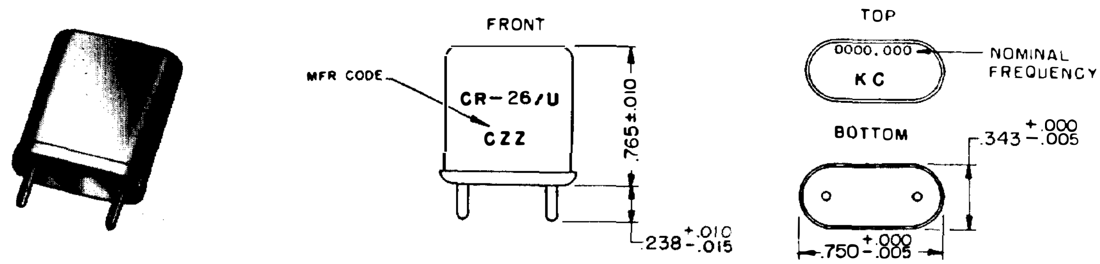


Figure 2-15. Crystal Unit CR-26/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium frequency control in circuits where superior frequency stability is required. This crystal unit is intended to be mounted in a temperature-controlled oven, and operated at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 200 to 500 kc

Nominal Frequency Tolerance: ±0.002% at 75°C

Frequency Deviation with Temperature: ±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C

Operating Temperature Range: 75° ±5°C

Operable Temperature Range: —40° to +80°C ±2°C

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level: 2 mw

Maximum Pin-to-Pin Capacitance: Not specified

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
200 to 249.999	3000
250 to 299.999	4000
300 to 399.999	5000
400 to 449.999	7500
450 to 500	10,000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, transitron, Meacham-bridge, modified Colpitts, modified Butler

MOUNTING DATA

Crystal Holder: HC-6/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-15(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X526-frequency in kc

Status: Standard (Category 1)

Date of Status: 9 October 1950

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: Certain waivers from specification are required by some manufacturers before they will produce this unit.

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

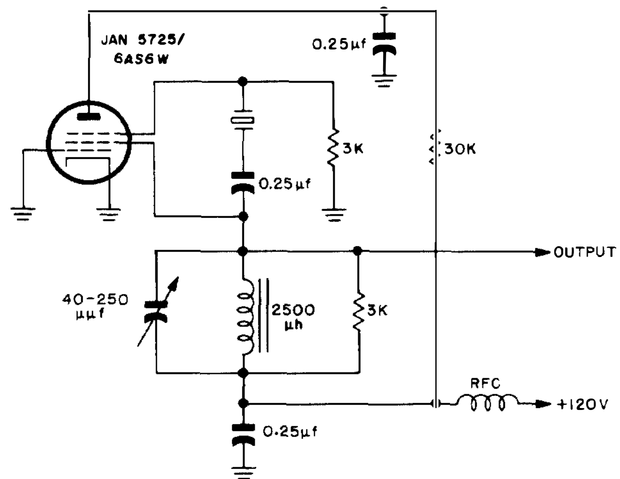


Figure 2-16. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-26/U

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.0005%
Permitted change in effective resonance resistance: ±15%

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
200 to 249.999	700
250 to 319.999	500
320 to 368.999	400
370 to 434.999	300
435 to 500	250

CRYSTAL UNIT CR-27/U
(MF—HF)

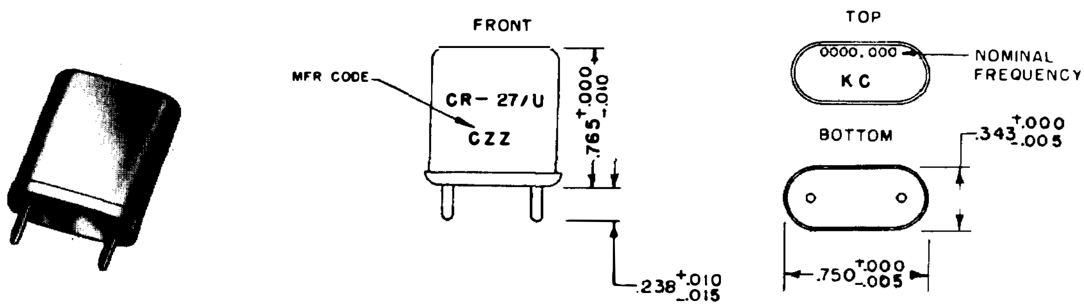


Figure 2-17. Crystal Unit CR-27/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature: ±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —55° to +90°C ±2°C
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level:
800 to 9,999.999 (5 mw)
10,000 to 20,000 (2.5 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	500
2250 to 2,999.999	320
3000 to 3,749.999	175
3750 to 4,749.999	120
4750 to 5,999.999	75
6000 to 7,499.999	50
7500 to 9,999.999	35
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, -114, figures 1-49, -50, -115, -118.

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-17(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X527-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.

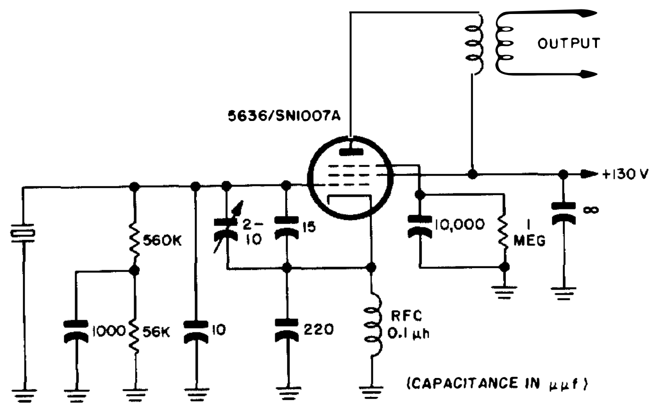


Figure 2-18. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-27/U

Remarks:

Equipment Used In:

Receiver-Transmitter RT-173/ARC-33 (see figures 1-135(S), (T), (U))

Receiver-Transmitter RT-178/ARC-27 (see figure 1-137(A))

Radio Set AN/ARC-34 (XA-1) (see figures 1-137(P), (Q), (R), (S))

Radio Transmitting Set AN/GRT-3 (1750 crystals)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set:

Crystal Impedance Meter TS-330/TSM (800 to 14,999.999 kc)

Crystal Impedance Meter TS-683/TSM (15,000 to 20,000 kc)

Electrical Connection of Holder:

Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure:

800 to 14,999.999 kc: MS90167 (see paragraph 2-60 and MIL-C-3098B)

15,000 to 20,000 kc: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Not required

CRYSTAL UNIT CR-28/U
(MF—HF)

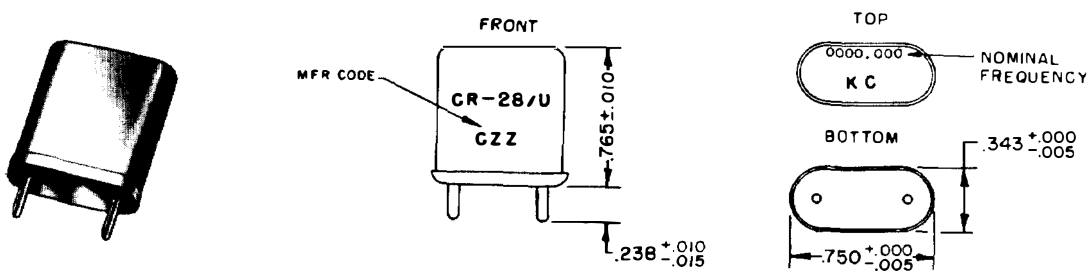


Figure 2-19. Crystal Unit CR-28/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature:
±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: −55° to +90°C ±2°C
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level:
800 to 9,999.999 (5 mw)
10,000 to 20,000 (2.5 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	800
1000 to 1,249.999	500
1250 to 1,499.999	400
1500 to 1,749.999	350
1750 to 1,999.999	300
2000 to 2,249.999	250
2250 to 3,749.999	150
3750 to 4,999.999	100
5000 to 6,999.999	50
7000 to 9,999.999	30
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, 1-114, figures 1-49, -50, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, transitron, modified Colpitts

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-19(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X528-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None

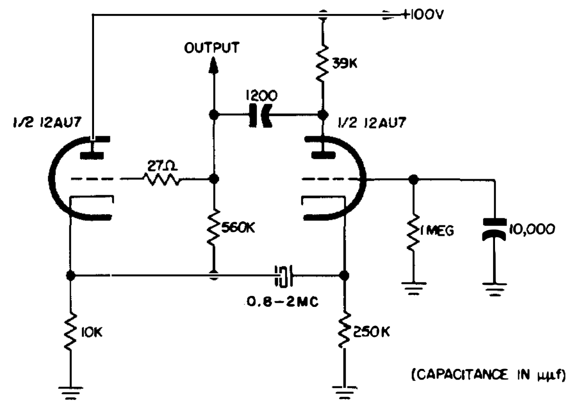


Figure 2-20. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-28/U

Equipment Used In: Receiver-Transmitter RT-173/ARC-33 (see figure 1-175(D))

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set:
- Crystal Impedance Meter TS-330/TSM (800 to 14,999.999 kc)
- Crystal Impedance Meter TS-683/TSM (15,000 to 20,000 kc)

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure:
- *800 to 14,999 kc:* MS90167 (see paragraph 2-60 and MIL-C-3098B)
- *15,000 to 20,000 kc:* MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
- *Permitted change in frequency:* ±0.0005%
- *Permitted change in effective resonance resistance:* ±15% or 2 ohms, whichever is greater

Aging Test:
- *Permitted change in frequency:* ±0.001%

Tensile Strength Test (Minimum Requirements):
Not required

CRYSTAL UNIT CR-29/U
(LF)

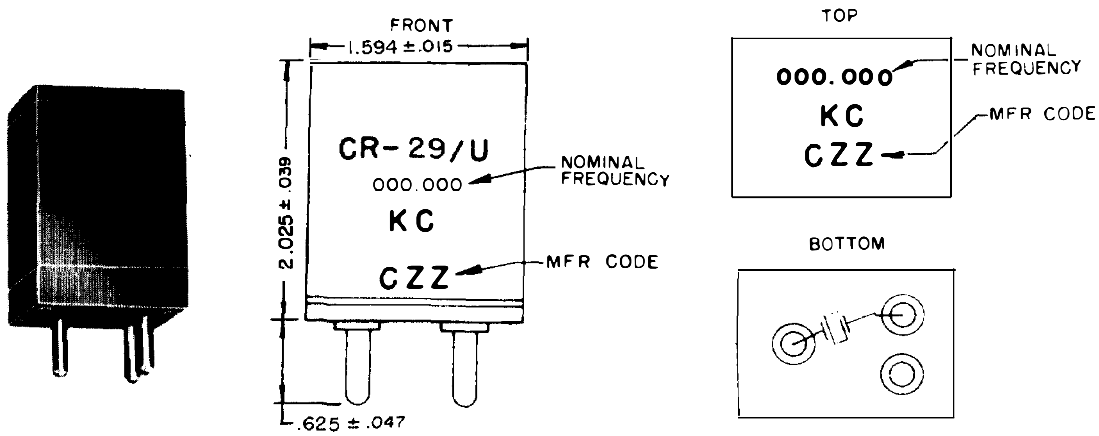


Figure 2-21. Crystal Unit CR-29/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a plastic holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 80 to 199.999 kc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature:
±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —40° to +80°C ±2°C
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
80 to 119.999	10,000
120 to 159.999	8000
160 to 199.999	6000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, transitron, Miller, modified Butler

MOUNTING DATA

Crystal Holder: HC-5/U or HC-21/U
Method of Mounting Crystal: Wire-mounted in plastic holder
Dimensions and Marking: See figure 2-21 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X529-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Use of this crystal unit is discouraged by some manufacturers because, in their opinion, the specified holder (HC-5/U) suffers these important disadvantages: The holder is not hermetically sealed (although a metal hermetically-

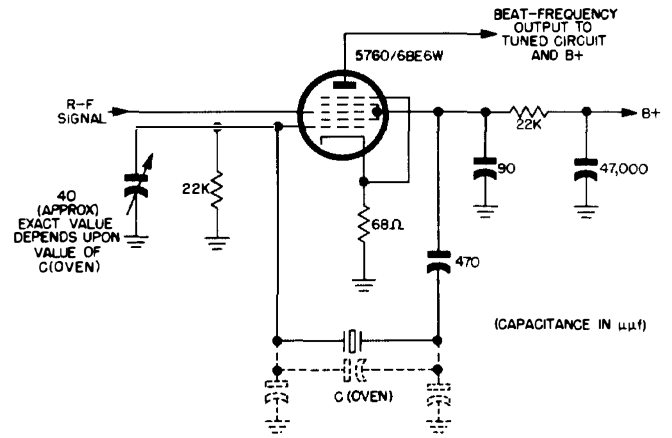


Figure 2-22. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-29/U

sealed version will be used in procurement of future models) ; it has a poor form factor; and it uses an unorthodox base which requires a special socket. In addition, the phenolic holder is even more detrimental at the 75° operating temperature.

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91483 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
80 to 119.999	1000
120 to 159.999	800
160 to 199.999	700

CRYSTAL UNIT CR-30/U
(LF)

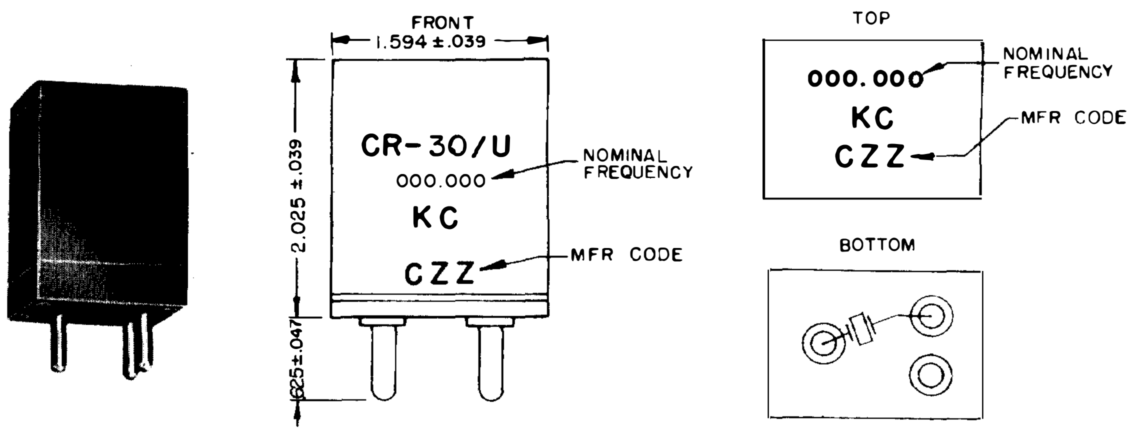


Figure 2-23. Crystal Unit CR-30/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a plastic holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operates at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 80 to 199.999 kc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature: ±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —40° to +80°C ±2°C
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance: 3000 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element D, paragraph 1-116, figure 1-52.

TYPES OF CIRCUITS USED IN

Meacham-bridge, two-stage-grounded-cathode, transitron, transformer-coupled, modified Butler

MOUNTING DATA

Crystal Holder: HC-5/U or HC-21/U
Method of Mounting Crystal: Wire-mounted in plastic holder
Dimensions and Marking: See figure 2-23(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X530-frequency in kc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Use of the crystal unit is discouraged by some manufacturers because, in their opinion, the specified holder (HC-5/U) suffers these important disadvantages: The holder is not hermetically sealed (although a metal hermetically-sealed version will be used in procurement of future models) ; it has a poor form factor; and it uses an unorthodox base which requires a special socket. In addition, the phenolic holder is even more detrimental at the 75° operating temperature.
Equipment Used In:

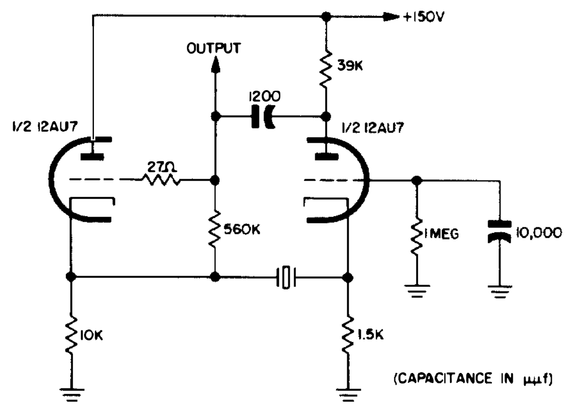


Figure 2-24. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-30/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.001%
Permitted change in effective resonance resistance: ±15%

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not specified

Frequency (kc)	*Grams*
80 to 119.999	1000
120 to 159.999	800
160 to 199.999	700

CRYSTAL UNIT CR-32/U (HF—VHF)

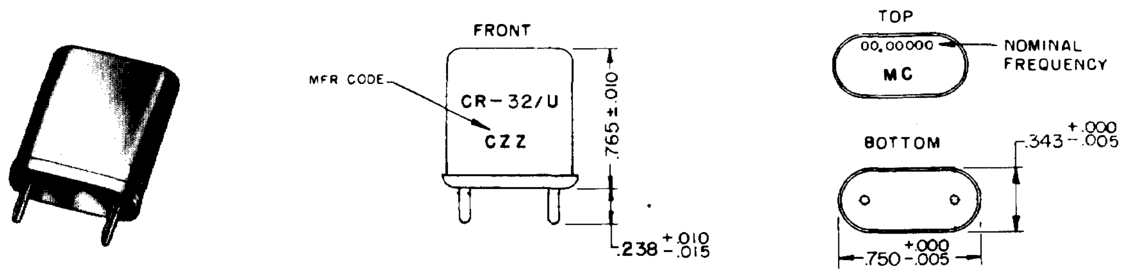


Figure 2-25. Crystal Unit CR-32/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the third and fifth mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high-to-very-high-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 10 to 75 mc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature:
±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —55° to +90°C ±2°C
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration:

Overtone	*Frequency (mc)*
Third	10 to 52
Fifth	52.000001 to 75

Maximum Drive Level:
10 to 24.999999 (2 mw)
25 to 75 (1 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
10 to 14.999999	60
15 to 52	40
52.000001 to 75	60

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, -114, figures 1-49, -50, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-25(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X532-frequency in mc
Status: Standard (Category 1)
Date of Status: 9 October 1950
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: This unit is difficult to manufacture to all specification requirements over the entire upper and lower frequency ranges.
Equipment Used In:
Receiver-Transmitter RT-173/ARC-33 (see figure 1-175(E))
Radio Set AN/ARC-34(XA-1) (see figure 1-175(I))
Radio Set AN/MRC-20 (11 crystals)
Radio Receiving Set AN/GRR-7 (1750 crystals)

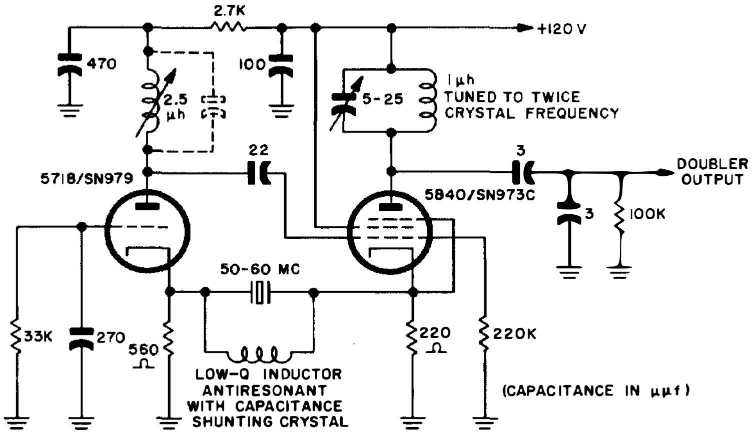


Figure 2-26. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-32/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS90168 (see paragraphs 2-62 and 2-64 per MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.0005%
Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test:
Permitted change in frequency: 0.001%

Tensile Strength Test (Minimum Requirements):
Not required

CRYSTAL UNIT CR-33/U (HF)

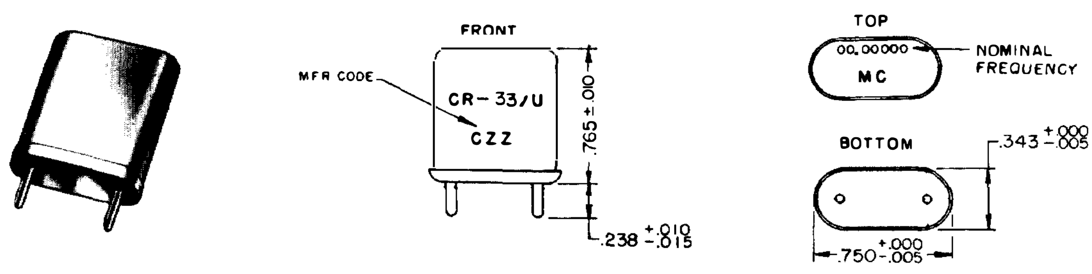


Figure 2-27. Crystal Unit CR-33/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in metal holder and designed to operate on the third mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 10 to 25 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: −55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Third overtone
Maximum Drive Level: 2.5 mw
Maximum Pin-to-Pin Capacitance: 12.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
10 to 10.999999	65
11 to 11.999999	60
12 to 12.999999	55
13 to 13.999999	50
14 to 14.999999	45
15 to 15.999999	41
16 to 16.999999	38
17 to 17.999999	36
18 to 18.499999	34
18.5 to 18.999999	32
19 to 19.499999	30
19.5 to 19.999999	28
20 to 20.499999	26
20.5 to 20.999999	25
21 to 21.499999	24
21.5 to 21.999999	23
22 to 22.499999	22
22.5 to 22.999999	21
23 to 23.499999	20
23.5 to 23.999999	19
24 to 24.499999	18
24.5 to 25	17

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Tuned-Pierce, tuned-Miller, Butler, modified Colpitts, capacitance-bridge, transformer-coupled, modified transitron

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-27 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

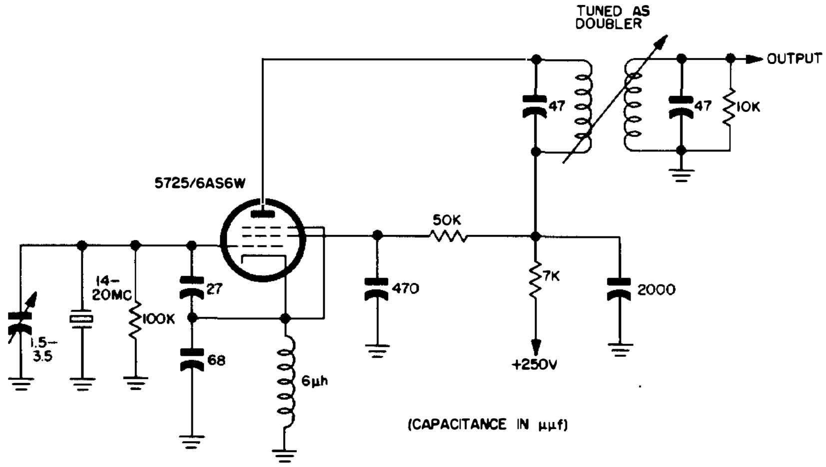


Figure 2-28. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-33/U

LOGISTICAL DATA

USAF Stock No.: 2100-2X533-frequency in mc
Status: Special application (Category 1)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None
Equipment Used In:
Radio Receiver R-252/ARN-14 (see figures 1-137(B), 1-138(A))
Radio Receiver R-252C/ARN-14 (34 crystals)
Radio Receiver R-541/ARN-14D (34 crystals)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955
Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50
Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM
Electrical Connection of Holder: Holder grounded
Method of Measuring Frequency and Effective Resonance Resistance: A
Drive Adjustment Procedure: MS91415 (see paragraph 2-63 and MIL-C-3098B)
Shock and Vibration Test:
Permitted change in frequency:
±0.0005% for units of 2000 kc and above
±0.001% for units below 2000 kc
Permitted change in effective resonance resistance: Wire-mounted — ±15% or 2 ohms, whichever is greater.
Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-35/U
(MF—HF)

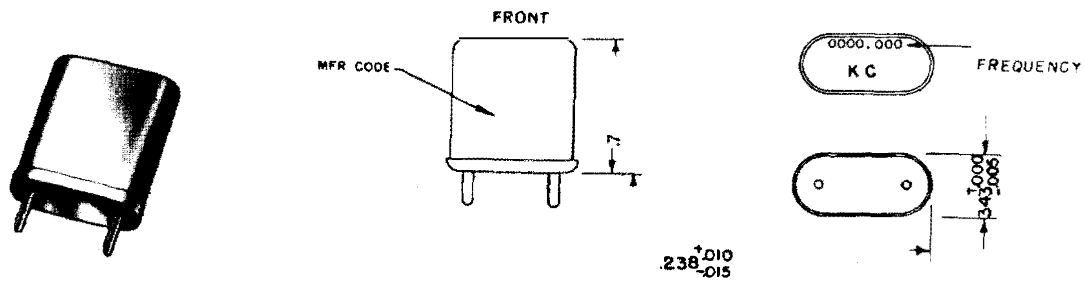


Figure 2-29. Crystal Unit CR-35/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc
Nominal Frequency Tolerance: ±0.002% at 85°C
Frequency Deviation with Temperature:
±0.0005% from frequency measured at 85°C permitted over range of 80° to 90°C
Operating Temperature Range: 85° ±5°C
Operable Temperature Range: —55° to +90°C ±2°C
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level:
800 to 9,999.999 kc (5 mw)
10,000 to 20,000 kc (2.5 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	800
1000 to 1,249.999	500
1250 to 1,499.999	400
1500 to 1,749.999	350
1750 to 1,999.999	300
2000 to 2,249.999	250
2250 to 3,749	
3750 to 4,999	
5000 to 6,999	
7000 to 9,999	
10,000 to 20,000	

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, -114, figures 1-49, -50, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, transitron, modified Colpitts

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-29(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X535-frequency in kc
Status: Standard (Category 1)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Complete information on long-term performance of crystals operating at the temperature specified for this unit is not yet available.
Equipment Used In:

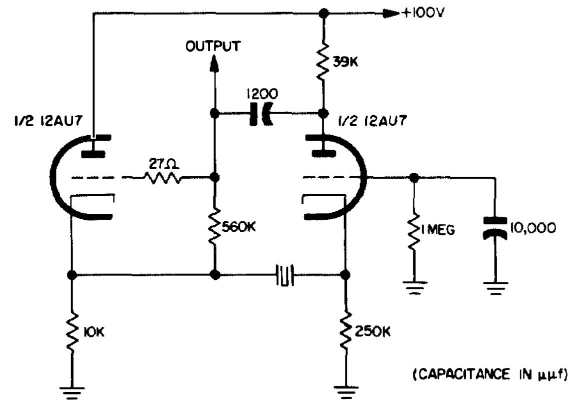


Figure 2-30. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-35/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set:
- Crystal Impedance Meter TS-330/TSM (800 to 14,999.999 kc)
- Crystal Impedance Meter TS-683/TSM (15,000 to 20,000 kc)

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure:
- *800 to 14,999.999 kc:* MS90167 (see paragraph 2-60 and MIL-C-3098B)
- *15,000 to 20,000 kc:* MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
- *Permitted change in frequency:* ±0.0005%
- *Permitted change in effective resonance resistance:* ±15% or 2 ohms, whichever is greater

Aging Test:
- *Permitted change in frequency:* ±0.001%

Tensile Strength Test (Minimum Requirements):
Not required

CRYSTAL UNIT CR-36/U (MF—HF)

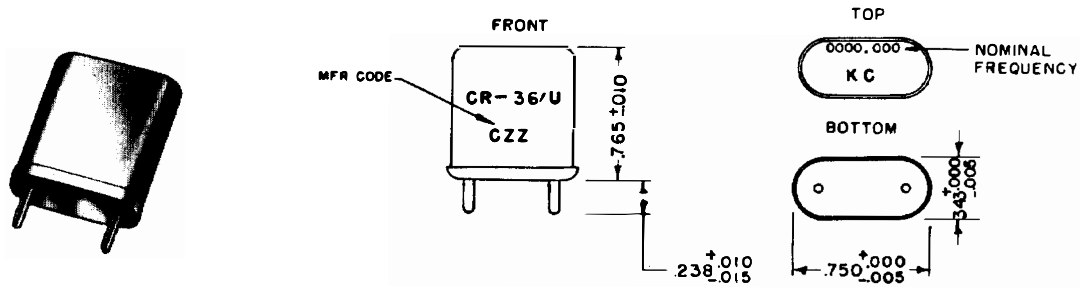


Figure 2-31. Crystal Unit CR-36/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc
Nominal Frequency Tolerance: ±0.002% at 85°C
Frequency Deviation with Temperature:
±0.0005% from frequency measured at 75°C permitted over the range of 80° to 90°C
Operating Temperature Range: 85° ±5°C
Operable Temperature Range: —55° to +90°C ±2°C
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level:
800 to 9,999.999 kc (5 mw)
10,000 to 20,000 kc (2.5 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	500
2250 to 2,999.999	320
3000 to 3,749.999	175
3750 to 4,749.999	120
4750 to 5,999.999	75
6000 to 7,499.999	50
7500 to 9,999.999	35
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, -114, figures 1-49, -50, -115, -118.

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-31(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X536-frequency in kc
Status: Standard (Category 1)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Complete information on long-term performance of crystals operating at the temperature specified for this unit is not yet available.
Equipment Used In: Radio Set AN/GRC-30 (42 crystals)

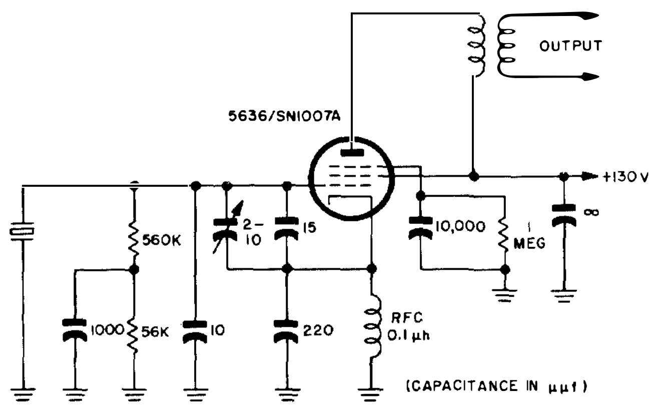


Figure 2-32. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-36/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set:
Crystal Impedance Meter TS-330/TSM (800 to 14,999.999 kc)
Crystal Impedance Meter TS-683/TSM (15,000 to 20,000 kc)

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure:
800 to 14,999.999 kc: MS90167 (see paragraph 2-60 and MIL-C-3098B)
15,000 to 20,000 kc: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.0005%
Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):
Not specified

CRYSTAL UNIT CR-37/U
(LF)

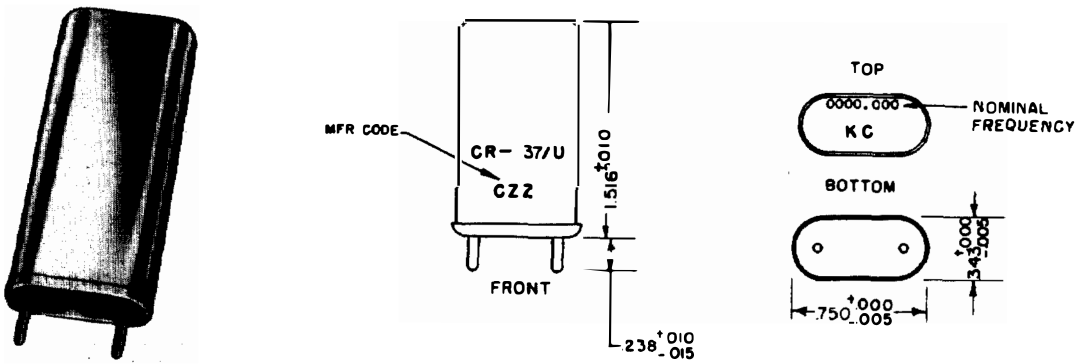


Figure 2-33. Crystal Unit CR-37/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits which need only minimum requirements in frequency stability in the absence of oven control under exposure to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 90 to 250 kc
Nominal Frequency Tolerance: ±0.02% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 20 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: See page 467.
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
90 to 169.999	5000
170 to 250	7000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element E, paragraph 1-199, figures 1-24, -25, -26.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, modified transitron, Miller, modified Butler

MOUNTING DATA

Crystal Holder: HC-13/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-33 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X537-frequency in kc
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None
Equipment Used In: Radio Set AN/ARN-27 (10 crystals)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

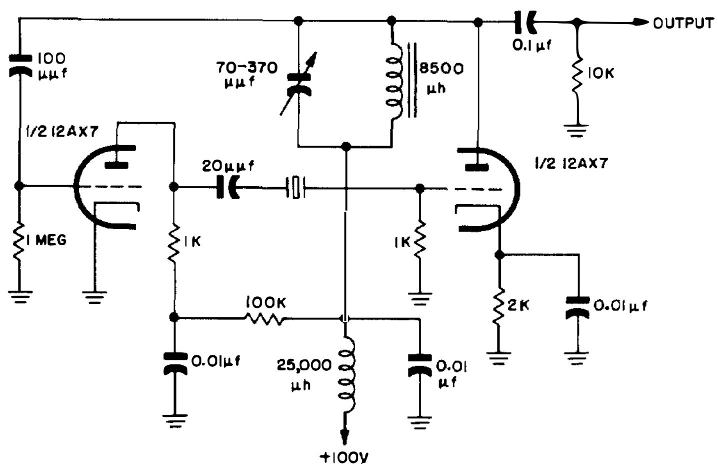


Figure 2-34. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-37/U

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM or TS-710/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B) or MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.001%
Permitted change in effective resonance resistance: ±15%

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
90 to 169.999	800
170 to 250	700

Capacitance: From pin-to-pin, where f is the specified frequency in kc per second

Frequency (kc) inclusive	*Permitted capacitance (μμf)*
90.000 to 169.999	$\frac{450}{f} + 1.2$, ±15%
170.000 to 250.999	$\frac{322}{f} + 1.2$, ±15%

CRYSTAL UNIT CR-38/U
(VLF—LF)

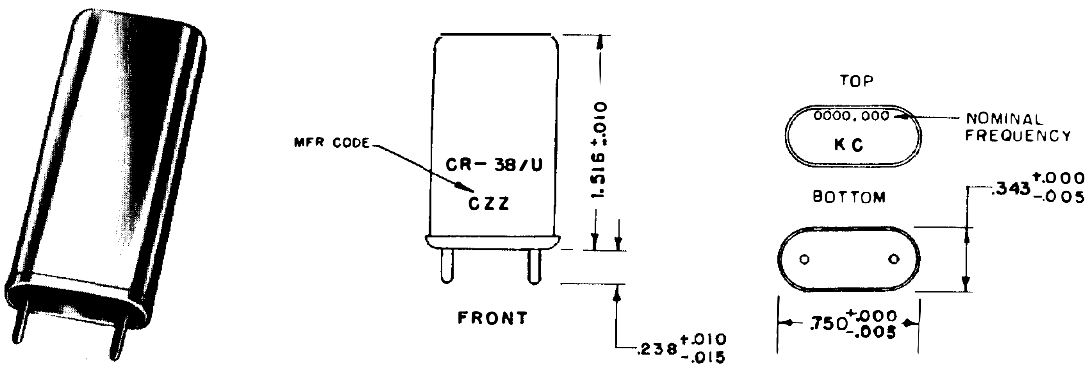


Figure 2-35. Crystal Unit CR-38/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency. of the quartz plate. Used as a very-low-to-low-frequency control element which need meet only average requirements in frequency stability in the absence of oven control when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 16 to 100 kc
Nominal Frequency Tolerance: ±0.012% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 20 ±0.5 $\mu\mu$f
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 0.1 mw
Maximum Pin-to-Pin Capacitance: See page 469.
Maximum Effective Resonance Resistance: 200,000 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element N, paragraph 1-104, figures 1-36, -37, -38.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, modified transitron

MOUNTING DATA

Crystal Holder: HC-13/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-35(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X538-frequency in kc
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None
Equipment Used In:

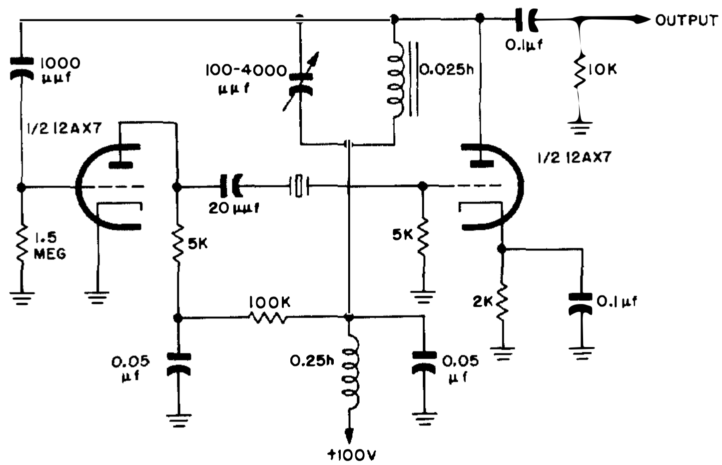


Figure 2-36. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-38/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-710/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.001%
Permitted change in effective resonance resistance: ±15%

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
16 to 59.999	800
60 to 100	700

Capacitance: From pin-to-pin, where f is the specified frequency in kc per second

Frequency (kc) inclusive	*Permitted capacitance (μμf)*
16.000 to 33.999	$\frac{24}{\sqrt{f}} + 1.6, \pm 15\%$
34.000 to 53.999	$\frac{33}{\sqrt{f}} + 1.6, \pm 15\%$
54.000 to 100.000	$\frac{24}{\sqrt{f}} + 1.6, \pm 15\%$

CRYSTAL UNIT CR-39/U
(LF—MF)

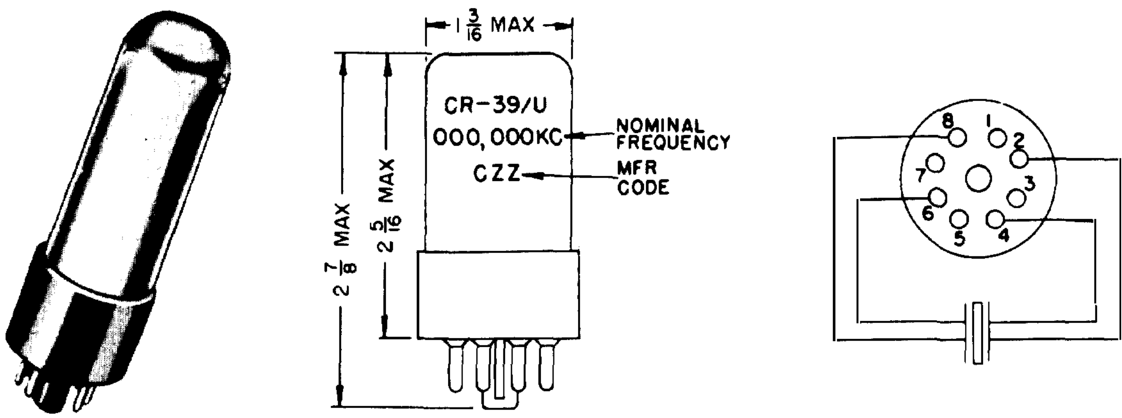


Figure 2-37. Crystal Unit CR-39/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in an evacuated glass-bulb holder (vacuum-tube type) and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element in circuits which must maintain unusually high frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 160 to 330 kc
Nominal Frequency Tolerance: ±0.003% at 25°C
Frequency Deviation with Temperature: ±0.004% from frequency measured at 25°C over range of −55° to +75°C ±2°C
Operating Temperature Range: −55° to +75°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 0.1 mw
Maximum Pin-to-Pin Capacitance:

Frequency (kc)	*Capacitance (μμf)*
160 to 249.999	$\frac{4320}{\text{Frequency (kc)}} + 2$
250 to 330	$\frac{1100}{\text{Frequency (kc)}} + 2$

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
160 to 249.999	150
250 to 330	600

Effective Resistance Deviation:

Frequency (kc)	*Resistance (ohms)*
160 to 249.999	50
250 to 330	200

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element G, paragraph 1-119, figures 1-55, -56, -117.

TYPES OF CIRCUITS USED IN

Meacham-bridge, two-stage-grounded-cathode, transitron, transformer-coupled, Butler, modified Colpitts

MOUNTING DATA

Crystal Holder: HC-15/U
Method of Mounting Crystal: Wire-mounted in an evacuated glass-bulb holder
Dimensions and Marking: See figure 2-37(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.

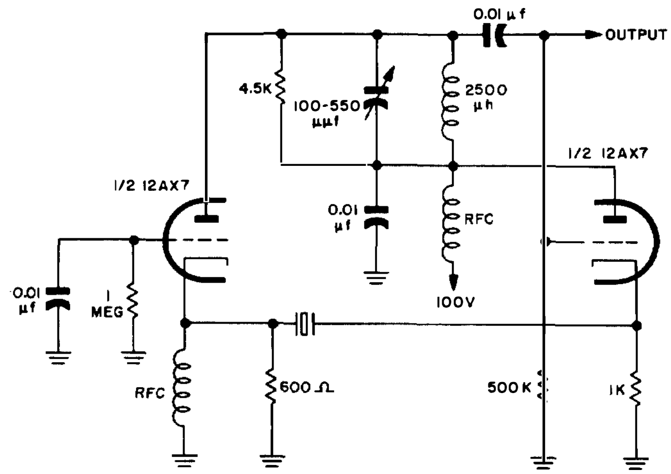


Figure 2-38. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-39/U

Commercial Sources: See Appendix III.

Remarks: Below 180 kc, the shortness of the holder relative to the size of the crystal blank increases the difficulty of obtaining a reliable crystal unit.

Equipment Used In: Radio Set AN/APN-5

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-710/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:
- *Permitted change in frequency:* ±0.00015%
- *Permitted change in effective resonance resistance:* 15%

Aging Test:
- *Permitted change in frequency:* ±0.000075% per week

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
160 to 249.999	1000
250 to 330	800

CRYSTAL UNIT CR-40/U (LF—MF)

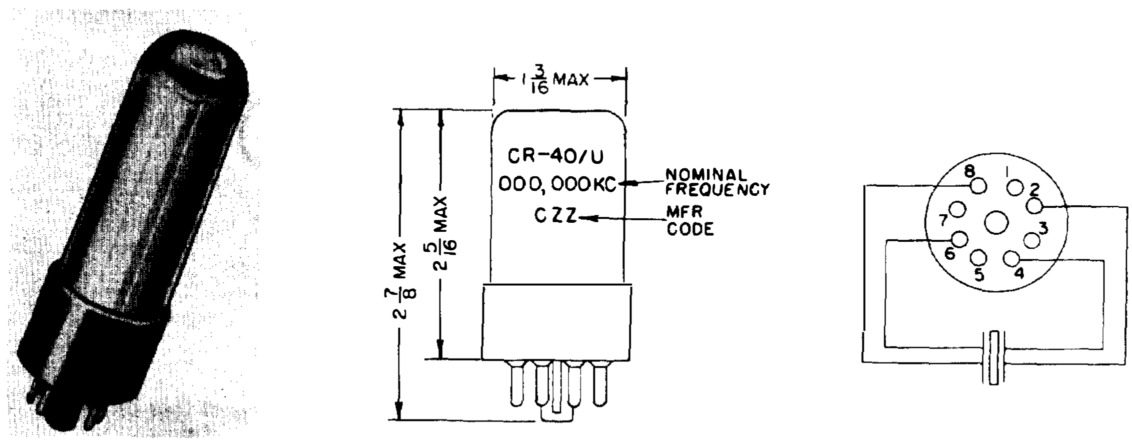


Figure 2-39. Crystal Unit CR-40/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in an evacuated glass-bulb holder (vacuum-tube type) and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven and operated at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 160 to 330 kc
Nominal Frequency Tolerance: ±0.003% at 70°C
Frequency Deviation with Temperature: ±0.0005% from frequency measured at 70°C permitted over range of 65° to 75°C
Operating Temperature Range: 70° ±5°C
Operable Temperature Range: −55° to +75° ±2°C
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 0.1 mw
Maximum Pin-to-Pin Capacitance:

Frequency (kc)	*Capacitance (μμf)*
160 to 249.999	$\frac{4320}{\text{Frequency (kc)}} + 2$
250 to 330	$\frac{1100}{\text{Frequency (kc)}} + 2$

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
160 to 249.999	150
250 to 330	600

Effective Resistance Deviation:

Frequency (kc)	*Resistance (ohms)*
160 to 249.999	50
250 to 330	200

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element G, paragraph 1-119, figures 1-55, -56, -117.

TYPES OF CIRCUITS USED IN

Meacham-bridge, two-stage-grounded-cathode, transitron, transformer-coupled, Butler, modified Colpitts

MOUNTING DATA

Crystal Holder: HC-15/U
Method of Mounting Crystal: Wire-mounted in evacuated glass-bulb holder
Dimensions and Marking: See figure 2-39(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X640
Status: Special application (Category 2)

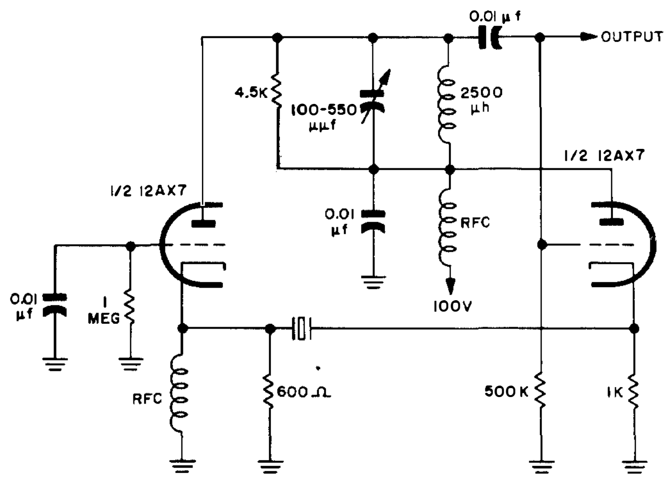


Figure 2-40. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-40/U

Date of Status: 19 November 1952

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: Below 180 kc, the shortness of the holder relative to the size of the crystal blank increases the difficulty of obtaining a reliable crystal unit.

Equipment Used In: Radio Set AN/CPN-2A

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Not applicable

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.00015%

Permitted change in effective resonance resistance: ±10% or 10 ohms, whichever is greater

Aging Test:

Permitted change in frequency: ±0.00005% per week

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
160 to 249.999	1000
250 to 330	800

CRYSTAL UNIT CR-42/U (LF)

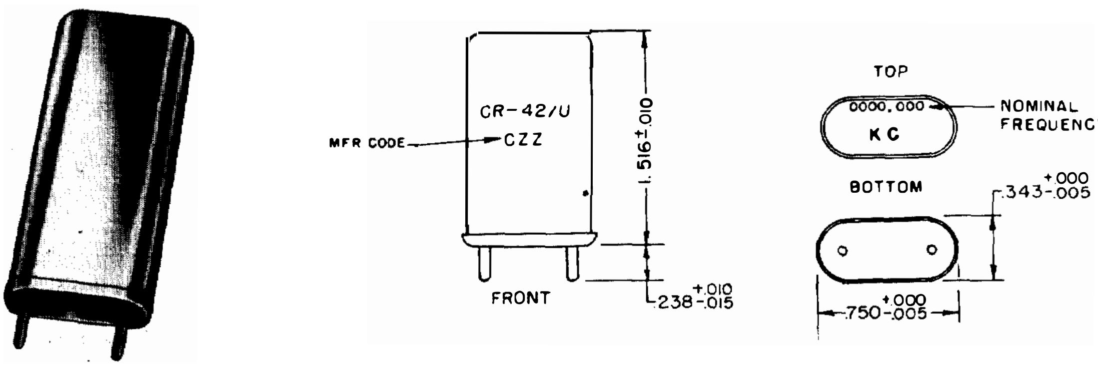


Figure 2-41. Crystal Unit CR-42/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in an evacuated glass-bulb holder (vacuum-tube type) and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 90 to 250 kc
Nominal Frequency Tolerance: ±0.003% at 75°C
Frequency Deviation with Temperature: ±0.002% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —55° to +85°C ±2°C
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
90 to 169.999	4500
170 to 250	7000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element E, paragraph 1-99, figures 1-24, -25, -28.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, Miller, modified transitron, modified Butler, Pierce

MOUNTING DATA

Crystal Holder: HC-13/U
Method of Mounting Crystal: Wire-mounted in an evacuated glass-bulb holder
Dimensions and Marking: See figure 2-41 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-2X542
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None
Equipment Used In: Radio Set AN/ARC-21

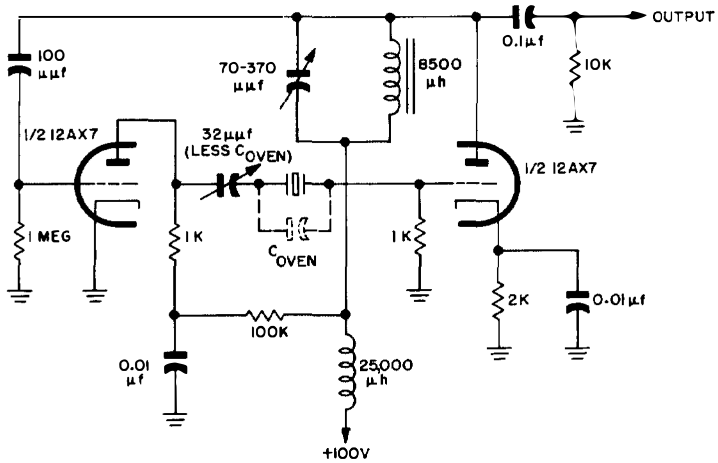


Figure 2-42. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-42/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM or TS-710/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B) or MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: —0.001 to +0.0005%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: —0.001 to +0.0005%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
90 to 169.999	800
170 to 250	700

CRYSTAL UNIT CR-43/U
(LF)

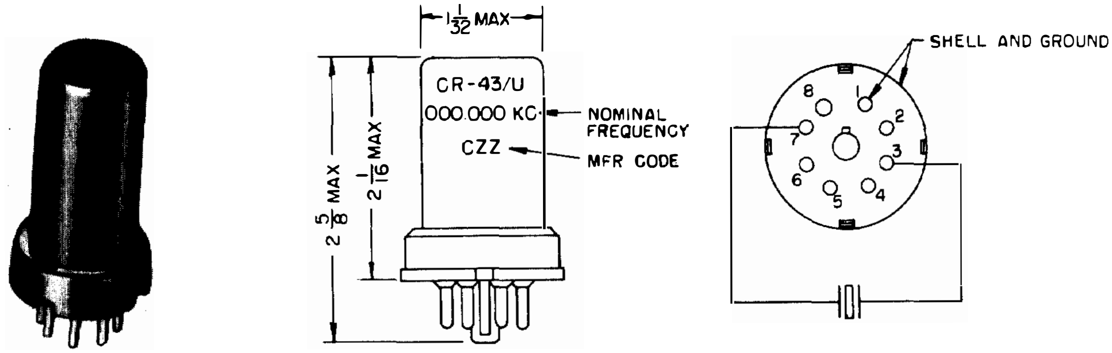


Figure 2-43. Crystal Unit CR-43/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in an evacuated metal-shell holder (vacuum-tube type) and designed to operate on the fundamental frequency of the quartz plate. Used as a low-frequency control element in circuits which must maintain good frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 80.860 kc (can be fabricated within a range of 70 to 100 kc)

Nominal Frequency Tolerance: ±0.01% at 25°C

Frequency Deviation with Temperature: ±0.0005% from frequency measured at 25°C permitted over range of —30° to +75°C ±2°C

Operating Temperature Range: —30° to +75°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range

Resonance: Parallel

Load Capacitance: 45 ±1.0 μμf

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level: 2 mw

Maximum Pin-to-Pin Capacitance: 45 μμf

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
80.860	3000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element M, paragraph 1-103, figures 1-33, -34, -35. (Optional: element E, paragraph 1-99, figures 1-24, -25, -26.)

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, Miller, modified transitron

MOUNTING DATA

Crystal Holder: HC-16/U

Method of Mounting Crystal: Wire-mounted in evacuated metal-shell holder

Dimensions and Marking: See figure 2-43(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100- 2X543-80.86

Status: Special application (Category 2)

Date of Status: 19 November 1952

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: The shortness of the crystal holder relative to the size of the crystal blank increases the difficulty of obtaining a reliable crystal unit. This unit is used in equipment for controlling mile pulses.

Equipment Used In:

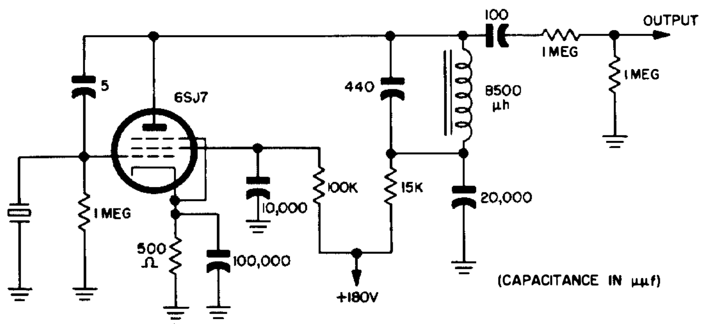


Figure 2-44. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-43/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

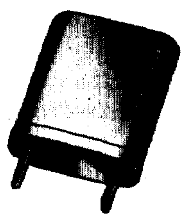
Aging Test:

Permitted change in frequency: ±0.00075% per week

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
80.860	1000

CRYSTAL UNIT CR-44/U *
(HF)



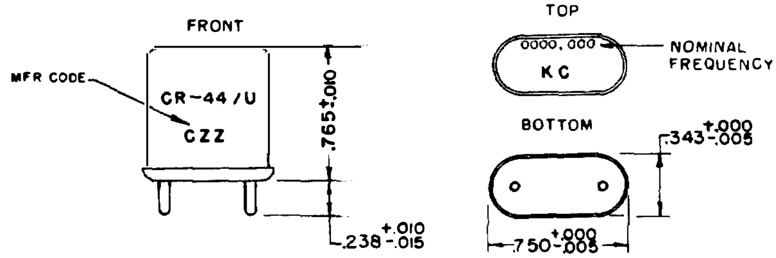


Figure 2-45. Crystal Unit CR-44/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a high-frequency control element in circuits where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 15,000 to 20,000 kc.
Nominal Frequency Tolerance: ±0.002% at 85°C
Frequency Deviation with Temperature: ±0.0005% from frequency measured at 85°C permitted over range of 80° to 90°C
Operating Temperature Range: 85° ±5°C
Operable Temperature Range: —55° to +90° ±2°C
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 1 mw
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance: 25 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements A and B, paragraphs 1-112, -114, figures 1-49, -50, -115, -118.

TYPES OF CIRCUITS USED IN

Pierce, Miller

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-45(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: *For replacement only. For new applications specify CR-36/U.

Equipment Used In: Radio Set AN/GRC-30 (42 crystals)

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955
Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.
Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

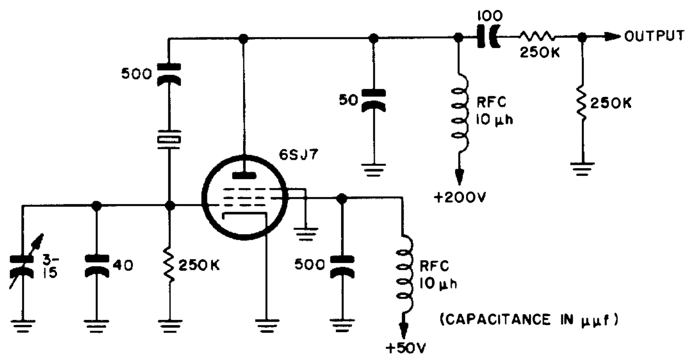


Figure 2-46. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-44/U

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.0005%
Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test: Not required

Tensile Strength Test (Minimum Requirements):
Not required

CRYSTAL UNIT CR-45/U
(MF)

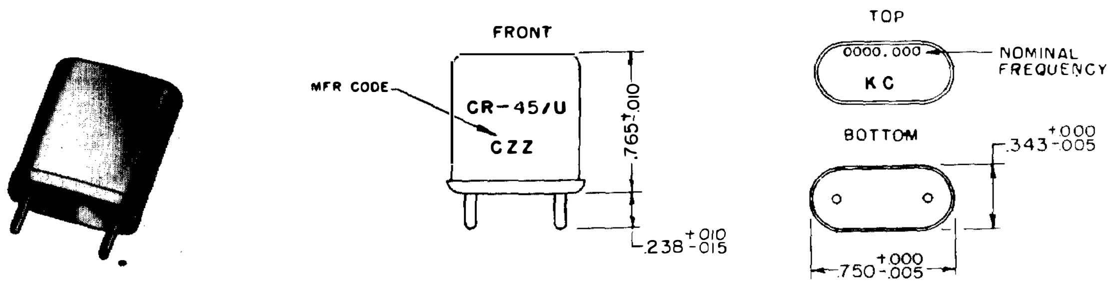


Figure 2-47. Crystal Unit CR-45/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a 455-kc i-f filter element in radio receiver circuits which must provide greater selectivity and i-f stability than can be obtained with conventional L-C bandpass circuits. The crystal unit is intended for operation at series resonance without oven control of the temperature.

RATED OPERATING CHARACTERISTICS

Frequency Range: 455 kc
Nominal Frequency Tolerance: ±0.02% at all temperatures within operating range
Special requirements: (a) The crystal unit shall have a difference in frequency of +80 ±12 cycles between operating at the series resonant frequency and parallel-resonance of 32 ±0.5 μμf. These tests shall be made at room temperature. (b) The crystal unit shall be free of spurious response within 7 kc of the nominal frequency.
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: −40° to +70° ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: 5 ±2.5 μμf
Maximum Effective Resonance Resistance: 3300 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element C, paragraph 1-115, figure 1-51.

TYPES OF CIRCUITS USED IN

Radio receiver i-f bandpass filters, capacitance-bridge

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-47(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: None
Equipment Used In:

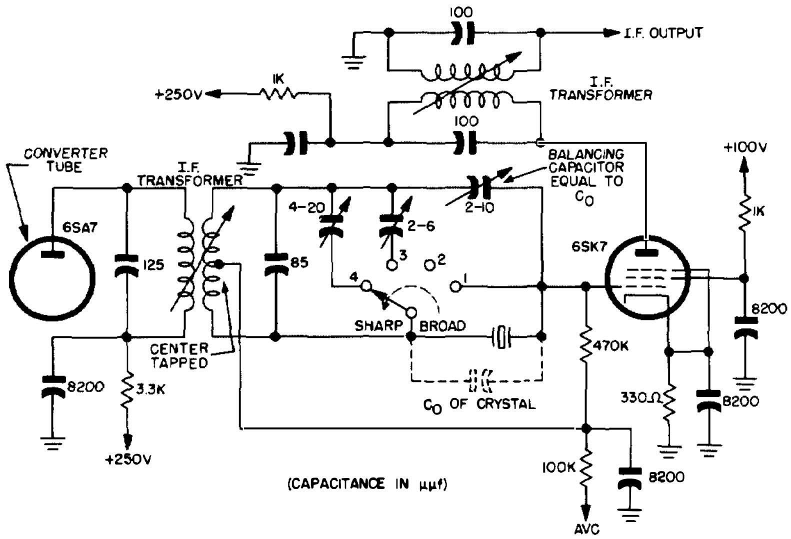


Figure 2-48. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-45/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.003%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): 500 grams

CRYSTAL UNIT CR-46/U (LF—MF)

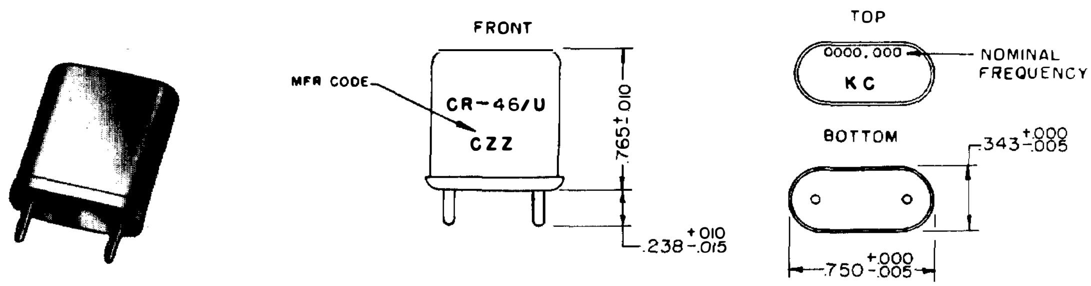


Figure 2-49. Crystal Unit CR-46/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element which must maintain good frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 200 to 500 kc
Nominal Frequency Tolerance: ±0.01% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70° ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 20 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
200 to 249.999	6500
250 to 299.999	7000
300 to 399.999	7500
400 to 449.999	10,000
450 to 500	11,000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements C and D, paragraphs 1-115, -116, figures 1-51, -52.

TYPES OF CIRCUITS USED IN

Miller, Pierce, multivibrator-type, modified transitron, two-stage-grounded-cathode

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-49(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Certain waivers from the specification are required by some manufacturers before going into production.
Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

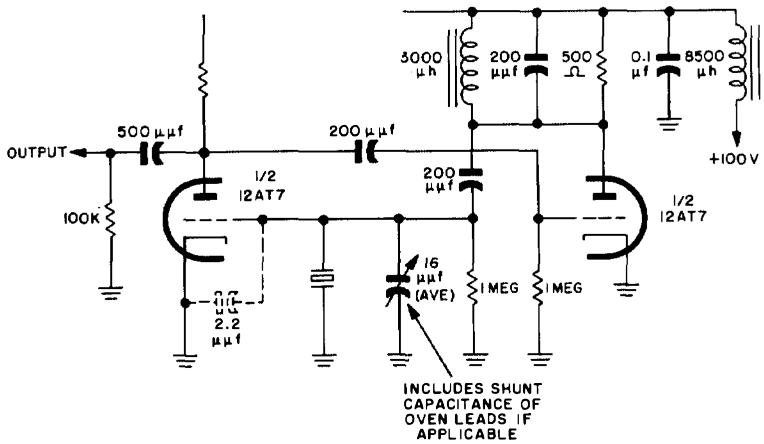


Figure 2-50. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-46/U

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.001%
Permitted change in effective resonance resistance: ±15%

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
200 to 249.999	700
250 to 319.999	500
320 to 369.999	400
370 to 434.999	300
435 to 500	250

CRYSTAL UNIT CR-47/U
(LF—MF)

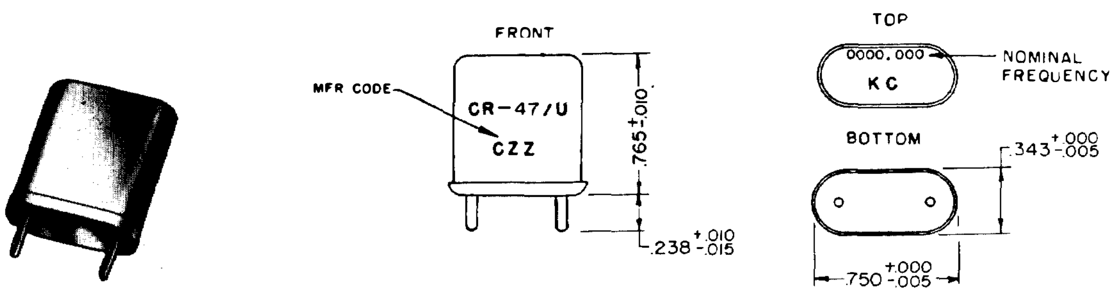


Figure 2-51. Crystal Unit CR-47/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a low-to-medium-frequency control element where superior frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven, and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 200 to 500 kc
Nominal Frequency Tolerance: ±0.002% at 75°C
Frequency Deviation with Temperature: ±0.0005% from frequency measured at 75°C permitted over range of 70° to 80°C
Operating Temperature Range: 75° ±5°C
Operable Temperature Range: —40° to +80° ±2°C
Resonance: Parallel
Load Capacitance: 20 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
200 to 249.999	6500
250 to 299.999	7000
300 to 399.999	7500
400 to 449.999	10,000
450 to 500	11,000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of elements C and D, paragraphs 1-115, -116, figures 1-51, -52.

TYPES OF CIRCUITS USED IN

Pierce, modified transitron, multivibrator-type, Miller, two-stage-grounded-cathode

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-51 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks:

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

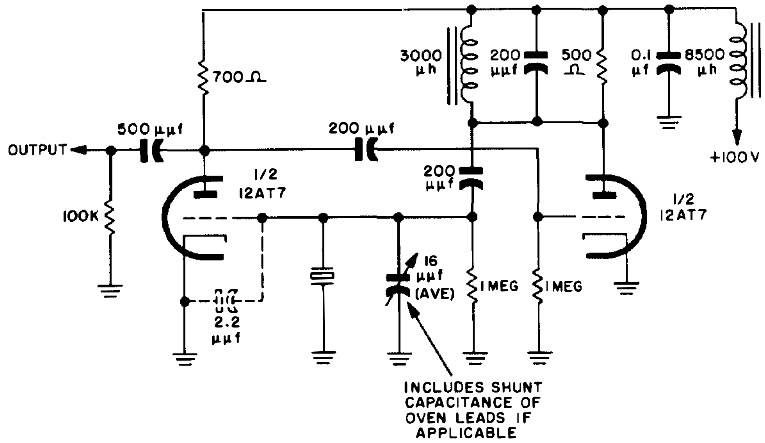


Figure 2-52. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-47/U

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-537/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91482 (see paragraph 2-61 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
200 to 249.999	700
250 to 319.999	500
320 to 369.999	400
370 to 434.999	300
435 to 500	250

CRYSTAL UNIT CR-48/U *
(MF)

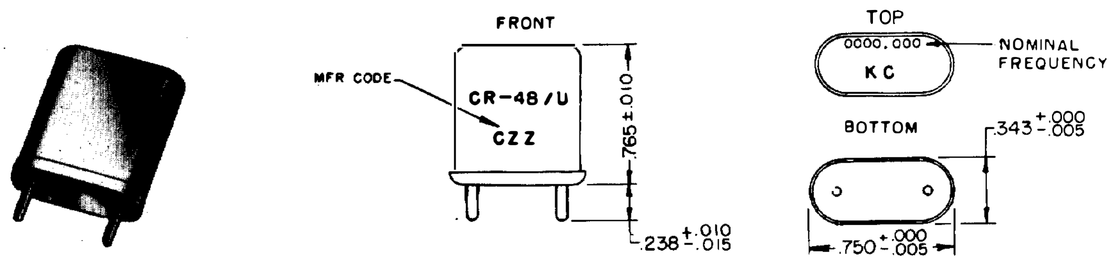


Figure 2-53. Crystal Unit CR-48/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-frequency control element in circuits which must maintain slightly better-than-average frequency stability when exposed to extreme variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 3000 kc
Nominal Frequency Tolerance: ±0.0075% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 10 mw
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	500
2250 to 3000	320

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -115, -118.

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-53 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 19 November 1952
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: *For replacement only. For new applications specify CR-18/U.
Equipment Used In:

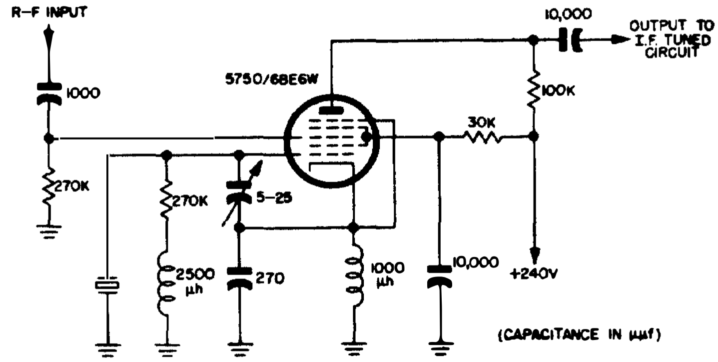


Figure 2-54. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-48/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-330/TSM

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS90167 (see paragraph 2-60 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency:
±0.001% for units below 2000 kc
±0.0005% for units of 2000 kc and above

Permitted change in effective resonance resistance: ±15%

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-49/U *
(MF)

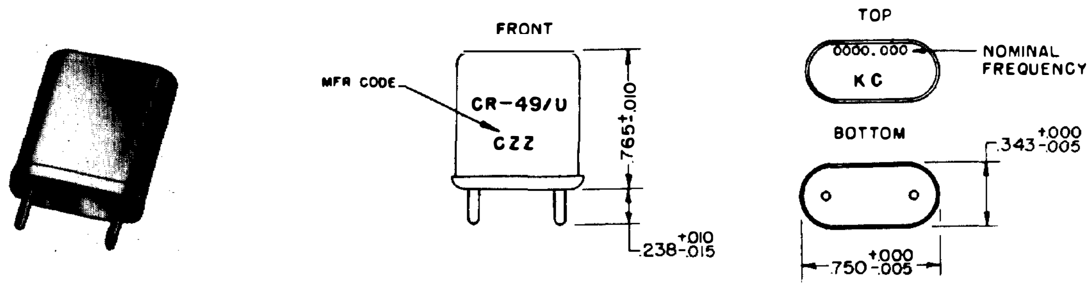


Figure 2-55. Crystal Unit CR-49/U

FUNCTIONAL DESCRIPTION

Spacer-mounted quartz plate in a metal holder designed to operate on the fundamental frequency of the quartz plate. Used as a medium-frequency control element in circuits which must maintain slightly better-than-average frequency stability under exposure to extreme variations in temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 3000 kc
Nominal Frequency Tolerance: ±0.0075% at all temperatures within operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: −55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Parallel
Load Capacitance: 32 ±0.5 μμf
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 10 mw
Maximum Pin-to-Pin Capacitance: Not specified
Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	500
2250 to 3000	320

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -115, -118.

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Spacer-mounted in metal holder
Dimensions and Marking: See figure 2-55 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: *For replacement only. For new applications specify CR-18/U.
Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955
Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.
Reference Standard Test Set: Crystal Impedance Meter TS-330/TSM

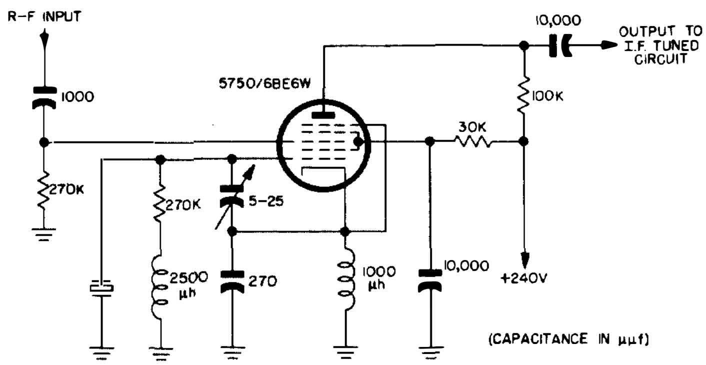


Figure 2-56. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-49/U

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: The crystal unit shall be subjected to a temperature run over the operating temperature range specified at any convenient rate of change not to exceed an average rate of 50°C per minute. Observations of frequency and effective resistance shall be made continuously, or intermittently at no greater than 2°C intervals. Values of frequency and effective resistance shall not exceed the prescribed limits over the temperature range.

Drive Adjustment Procedure: MS90167 (see paragraph 2-60 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency:

±0.002% for units below 2000 kc

±0.0005% for units of 2000 kc and above

Permitted change in effective resonance resistance:

Resistance (ohms)	*Permitted change (%)*
0 to 10	40
10.1 to 50	30
50.1 to 100	25
above 100	20

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-50/U
(VLF—LF)

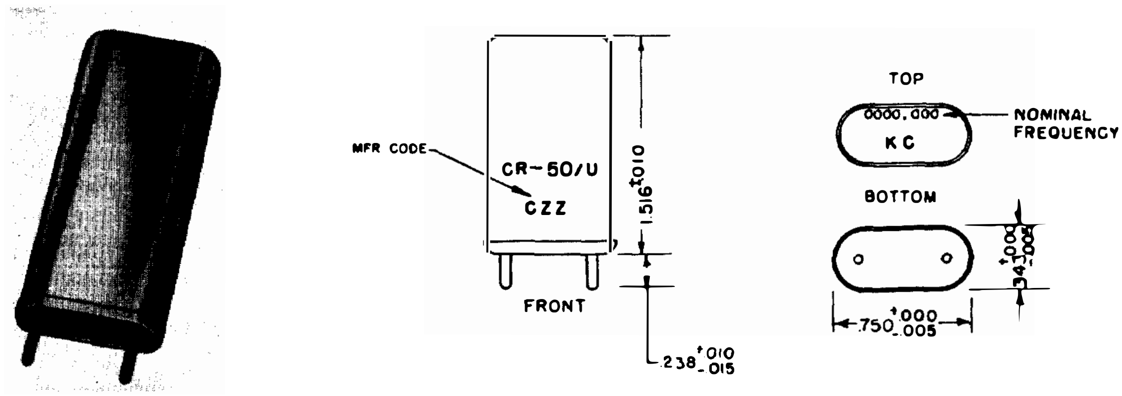


Figure 2-57. Crystal Unit CR-50/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a very-low-to-low-frequency control element which need meet only average requirements in frequency stability in the absence of oven control when exposed to wide variations in temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 16 to 100 kc
Nominal Frequency Tolerance: ±0.012% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within the limits of nominal frequency tolerance
Operating Temperature Range: —40° to +70°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fundamental
Maximum Drive Level: 0.1 mw
Maximum Pin-to-Pin Capacitance:

Frequency (kc)	*Capacitance (μμf)*
16 to 33.999	$\left(\frac{24}{\sqrt{\text{Frequency (kc)}}}+1.6\right) \pm 15\%$
34 to 53.999	$\left(\frac{33}{\sqrt{\text{Frequency (kc)}}}+1.6\right) \pm 15\%$

Frequency (kc)	*Resistance (ohms)*
54 to 100.00	$\left(\frac{24}{\sqrt{\text{Frequency (kc)}}}+1.6\right) \pm 15\%$

Maximum Effective Resonance Resistance: 125,000 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element N, paragraph 1-104, figures 1-36, -37, -38.

TYPES OF CIRCUITS USED IN

Two-stage-grounded-cathode, modified transitron

MOUNTING DATA

Crystal Holder: HC-13/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-57(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 2)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: The shunt-capacitance specification is controversial within the industry.
Equipment Used In: Radio Set AN/ARN-27 (10 crystals)

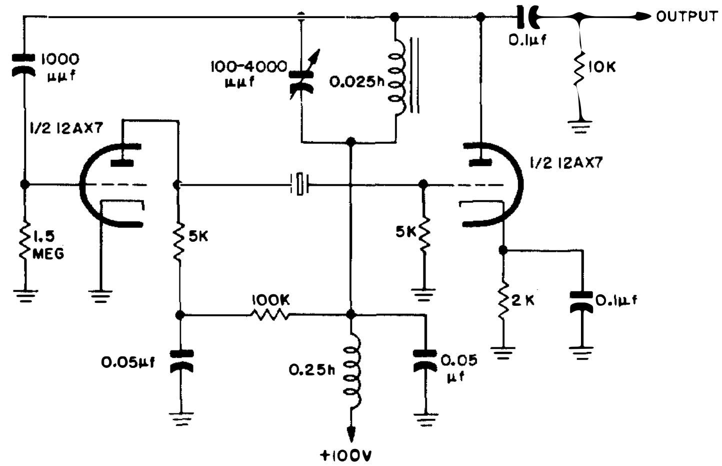


Figure 2-58. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-50/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-710/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.001%

Permitted change in effective resonance resistance: ±15%

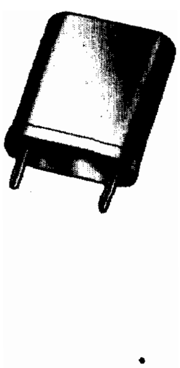
Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*
16 to 59.999	800
60 to 100	700

CRYSTAL UNIT CR-51/U (HF—VHF)



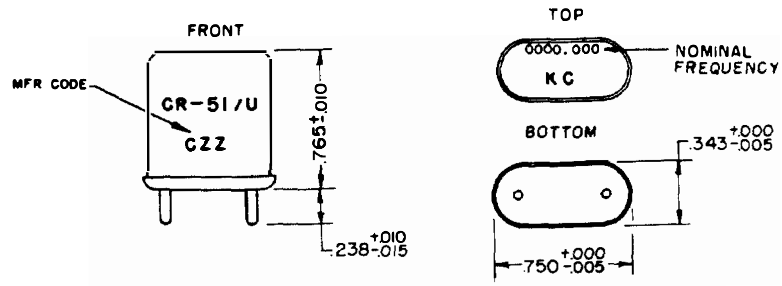


Figure 2-59. Crystal Unit CR-51/U

FUNCTIONAL DESCRIPTION

Pressure-mounted quartz plate in metal holder designed to operate on the third mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high- to very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations in temperature and to relatively high drive levels. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 10 to 61 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: −55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Third mechanical harmonic
Maximum Drive Level: 20 mw
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
10 to 14.999	60
15 to 61	40

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Pressure-mounted in metal holder
Dimensions and Marking: See figure 2-59(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 1)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Difficult to manufacture and meet all specification requirements over entire upper and lower ranges.
Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955
Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

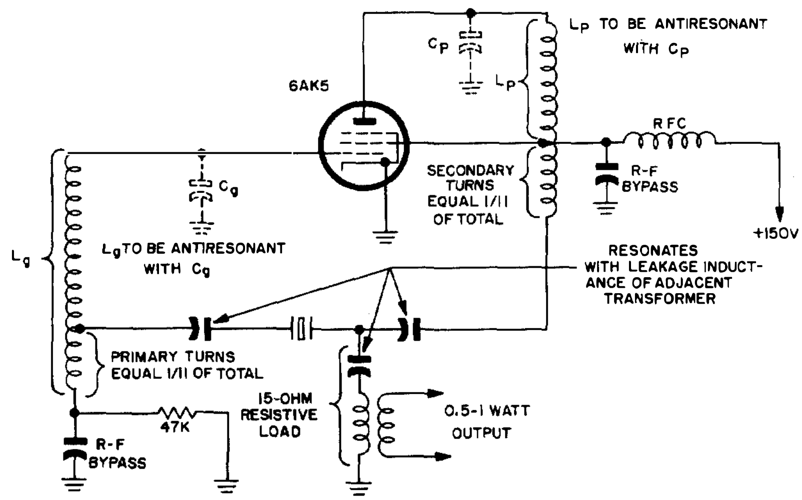


Figure 2-60. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-51/U

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A or B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B), with the exception of the following table of voltage and resistance:

Frequency (mc)	*Resistance (ohms)*	*Volts*
10 to 14.999	60	1.1
15 to 61	40	0.9

Shock and Vibration Test:

Permitted change in frequency: ±0.002%

Permitted change in effective resonance resistance: Shall not exceed the max effective resistance

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-52/U
(HF—VHF)

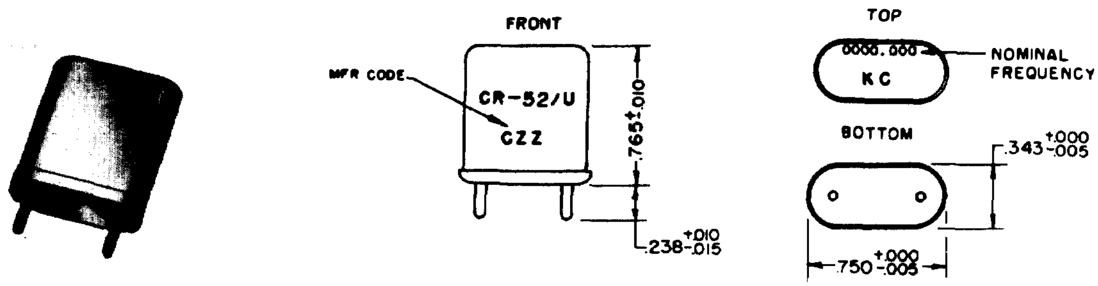


Figure 2-61. Crystal Unit CR-52/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the third mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high- to very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 10 to 61 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Third mechanical harmonic
Maximum Drive Level:
10 to 24.999999 mc (4 mw)
25 to 61 mc (2 mw)
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
10 to 14.999999	60
15 to 61	40

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-61(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 1)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.

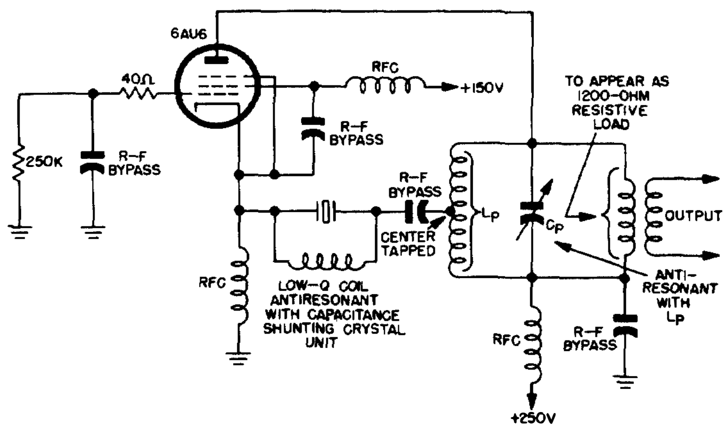


Figure 2-62. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-52/U

Remarks: Difficult to manufacture and meet all specification requirements over entire upper and lower ranges. Same as CR-23/U except designed to operate on 3rd mode only.

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS90168 (see paragraphs 2-62 and 2-64 per MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.005%

Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-53/U
(VHF)

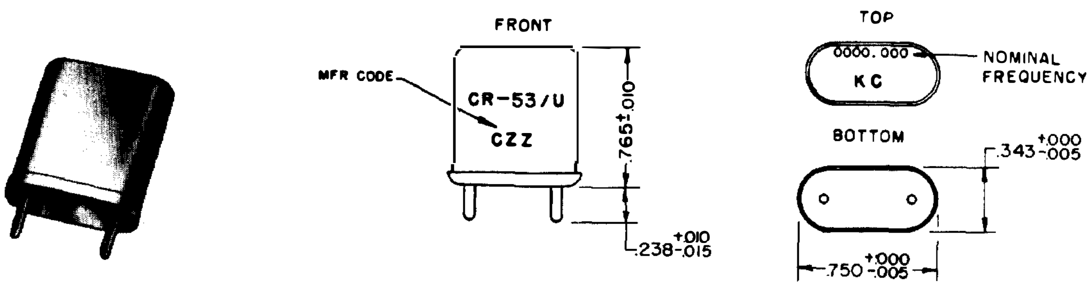


Figure 2-63. Crystal Unit CR-53/U

FUNCTIONAL DESCRIPTION

Pressure-mounted quartz plate in metal holder designed to operate on the fifth mechanical harmonic of the fundamental frequency of the quartz plate. Used as a very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations in temperature and to relatively high drive levels. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 50 to 87 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fifth mechanical harmonic
Maximum Drive Level: 20 mw
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance: 60 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Pressure-mounted in metal holder
Dimensions and Marking: See figure 2-63 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 1)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Some manufacturers cannot produce this unit over the entire upper or lower ranges and meet all requirements of the specification.
Equipment Used In:

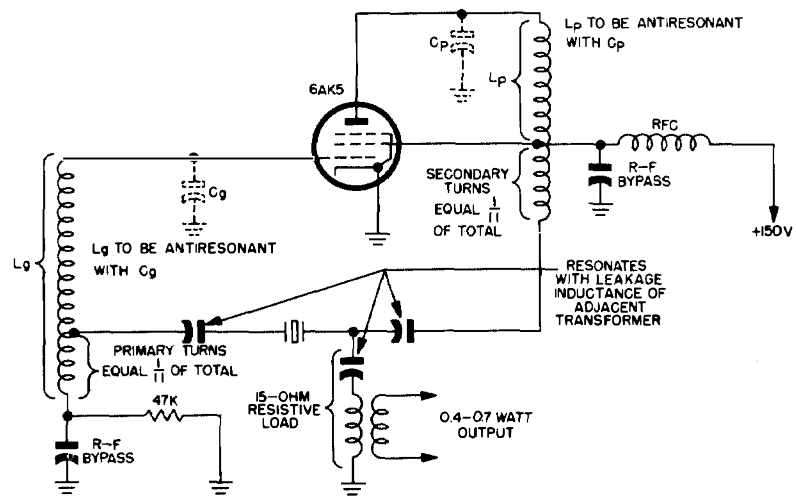


Figure 2-64. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-53/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A or B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B), with the exception that the resistance shall be 60 ohms and voltage shall be 1.1 volts.

Shock and Vibration Test:

Permitted change in frequency: ±0.002%

Permitted change in effective resonance resistance: Shall not exceed the max effective resistance

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-54/U (VHF)

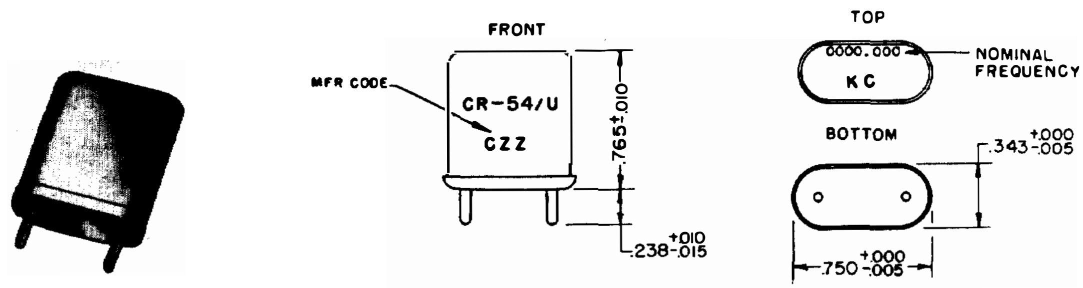


Figure 2-65. Crystal Unit CR-54/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fifth mechanical harmonic of the fundamental frequency of the quartz plate. Used as a very-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations in temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 50 to 87 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: —55° to +90°C ±2°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Fifth mechanical harmonic
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: 7.0 $\mu\mu$f
Maximum Effective Resonance Resistance: 60 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-6/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-65(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-
Status: Special application (Category 1)
Date of Status: 14 January 1954
Related Specifications, Standards, and Publications: See Appendix IV.
Commercial Sources: See Appendix III.
Remarks: Some manufacturers cannot produce this unit over the entire upper or lower ranges and meet all requirements of the specification. Same as CR-23/U except designed to operate on 5th mode only.
Equipment Used In:

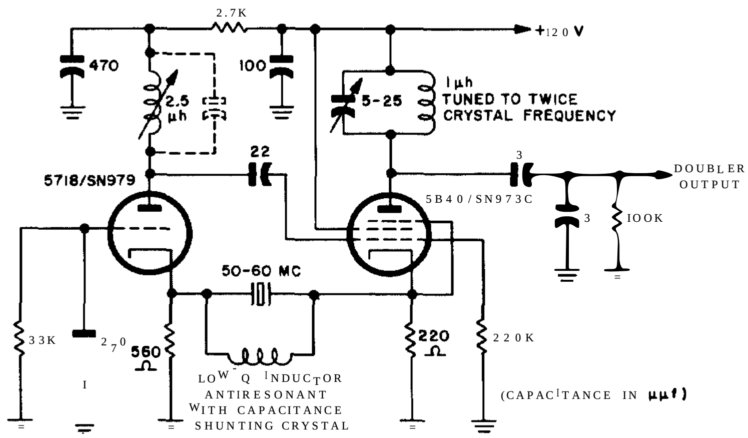


Figure 2-66. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-54/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS90168 (see paragraphs 2-62 and 2-64 per MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-55/U
(HF—VHF)

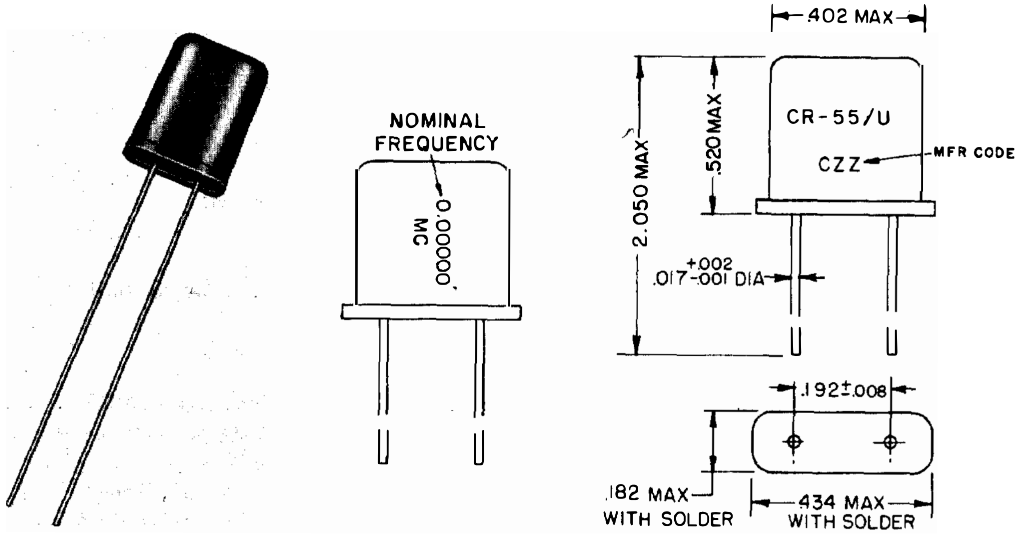


Figure 2-67. Crystal Unit CR-55/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a subminiature metal holder and designed to operate on the third mechanical harmonic of the fundamental frequency of the quartz plate. Used as a high- to very-high-frequency control element in transistor-cased or subminiature packaged circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to extreme variations in temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 17 to 61 mc
Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range
Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance
Operating Temperature Range: −55° to +105°C
Operable Temperature Range: Not specified beyond operating temperature range
Resonance: Series
Load Capacitance: Not applicable
Harmonic of Quartz Vibration: Third mechanical harmonic
Maximum Drive Level: 2 mw
Maximum Pin-to-Pin Capacitance: 7.0 μμf
Maximum Effective Resonance Resistance: 40 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118.

TYPES OF CIRCUITS USED IN

Transistor, Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-18/U
Method of Mounting Crystal: Wire-mounted in metal holder
Dimensions and Marking: See figure 2-67(B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

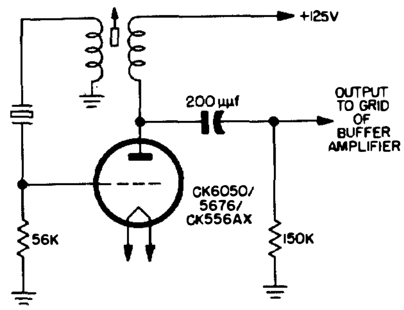


Figure 2-68. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-55/U

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Standard (Category 1)

Date of Status: 9 December 1955

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks: None

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-3098B, approved 9 December 1955

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure: MS90168 (see paragraphs 2-62 and 2-64 per MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15% or 2 ohms, whichever is greater

Aging Test: Not required

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-56/U

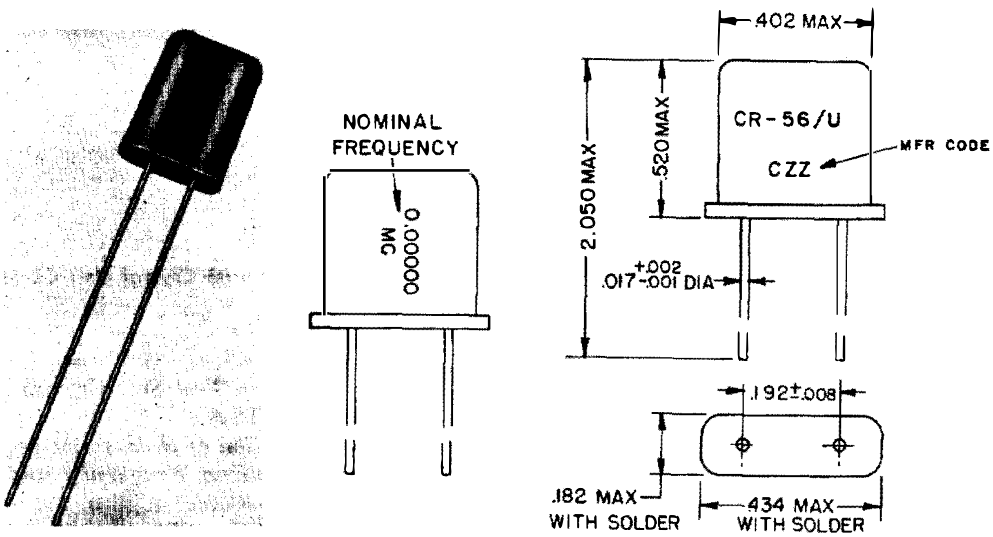


Figure 2-69. Crystal Unit CR-56/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a subminiature metal holder and designed to operate on the fifth harmonic of the fundamental frequency of the quartz plate. Used as a very-high-frequency control element in subminiature circuit applications which must maintain above-average frequency stability in the absence of oven control, even when exposed to extreme variations in temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 50 to 87 mc (Experimental Crystal Unit CR-56/U(XN-1) extends the frequency range to 121.5 mc)

Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range

Frequency Deviation with Temperature:

Operating Temperature Range: —55° to +105°C

Operable Temperature Range: Not specified - yond operating temperature range

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration: Fifth harmonic mode

Maximum Drive Level: 2 mw

Maximum Pin-to-Pin Capacitance: 7.0 μμf

Maximum Effective Resonance Resistance: 60 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-18/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-69 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

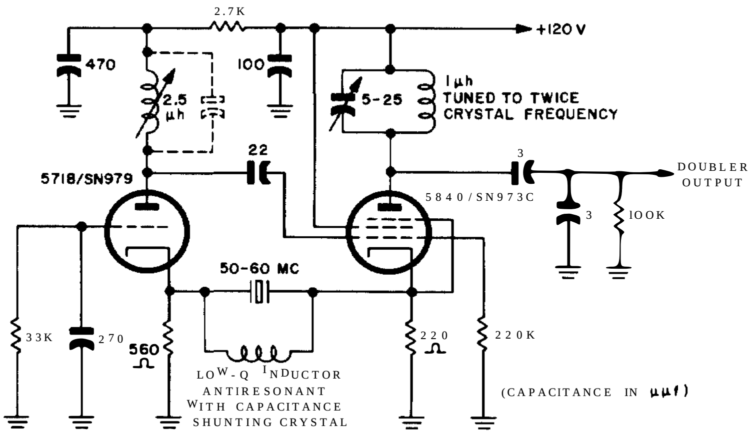


Figure 2-70. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-56/U

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Standard (Category 1)

Date of Status: 9 December 1955

Related Specifications, Standards, and Publications: See Appendix IV

Commercial Sources: See Appendix III

Remarks:

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: MIL-C-3098B (Date 9 Dec 1955)

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50.

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance:

Drive Adjustment Procedure: MS90168 (see paragraphs 2-62 and 2-64 per MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency: ±0.0005%
Permitted change in effective resonance resistance: ±15% or ohms, whichever is greater

Aging Test:
Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-57/U

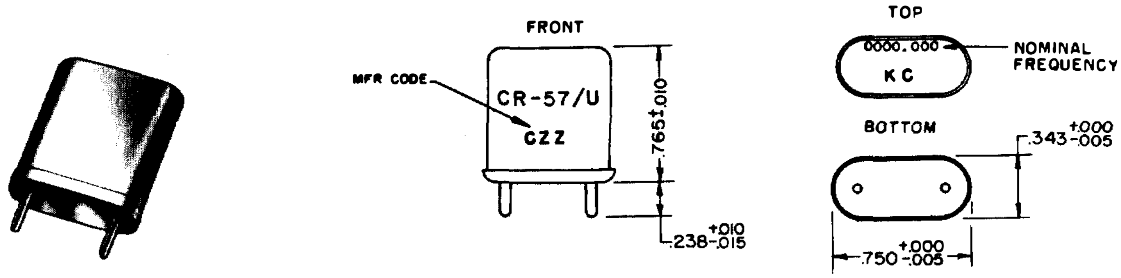


Figure 2-71. Crystal Unit CR-57/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a 500-kc control element in circuits where maximum frequency stability is required. The crystal unit is intended to be mounted in a temperature-controlled oven and operated at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 500 kc

Nominal Frequency Tolerance: ±0.001% at 85°C, ±1°C

Frequency Deviation with Temperature: ±0.0003% from the measured frequency at 85°C permitted over range of 80°C to 90°C

Operating Temperature Range: 85° ±5°C

Operable Temperature Range: —55° to +20° ±2°C, but not necessarily within tolerance on nominal frequency. 0.005% tolerance required from +20° to +80°C

Resonance: Parallel

Load Capacitance: 32.0 ±0.5 μμf

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level: 0.5 mw

Maximum Pin-to-Pin Capacitance: 7.0 μμf

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
500	3000

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element C, paragraph 1-115, figure 1-51

TYPES OF CIRCUITS USED IN

Pierce, Miller

MOUNTING DATA

Crystal Holder: HC-6/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-71 (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Special Application (Category 1)

Date of Status: 5 March 1956

Related Specifications, Standards, and Publications: See Appendix IV

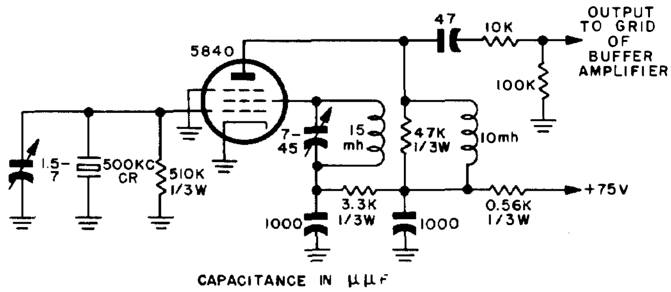


Figure 2-72. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-57/U

Commercial Sources: See Appendix III

Remarks:

Equipment Used In: R.F. Oscillator O-197/U, p/o Radio Set AN/ARC-21

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-25538 (USAF)

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50

Reference Standard Test Set: Crystal Impedance Meter TS-710/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS91446 (see paragraph 2-65 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15% or 2 ohms

Aging Test:

Permitted change in frequency: ±0.0005%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-58/U
(MF—HF)

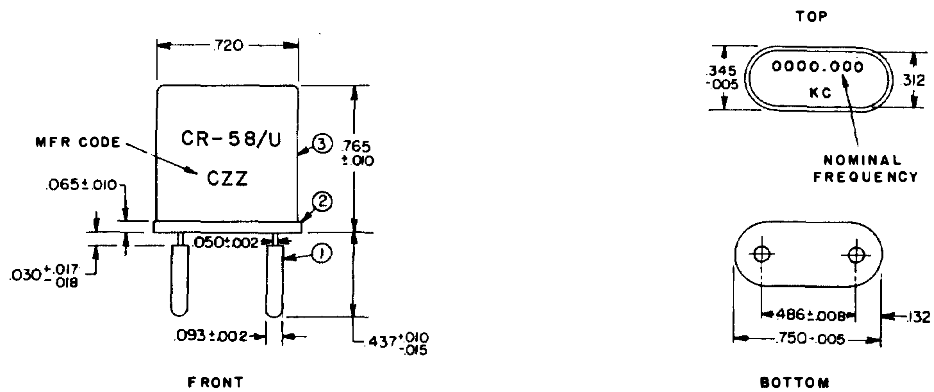


Figure 2-73. Crystal Unit CR-58/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits which must maintain above-average frequency stability in the absence of oven control, even when exposed to wide variations of temperature. The crystal unit is intended for operation at parallel resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 800 to 20,000 kc

Nominal Frequency Tolerance: ±0.005% at all temperatures within operating range

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: —55° to +90°C ±2°C

Operable Temperature Range: Not specified beyond operating temperature range

Resonance: Parallel

Load Capacitance: 32 ±0.5 mmf

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level:

800 to 9,999.999 kc—10 mw
10,000 to 20,000 kc—5 mw

Maximum Pin-to-Pin Capacitance: 7.0 mmf

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*
800 to 999.999	1000
1000 to 1,249.999	800
1250 to 1,499.999	700
1500 to 1,749.999	600
1750 to 1,999.999	550
2000 to 2,249.999	320
3000 to 3,749.999	175
3750 to 4,749.999	120
4750 to 5,999.999	75
6000 to 7,499.999	50
7500 to 9,999.999	35
10,000 to 20,000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118

TYPES OF CIRCUITS USED IN

Pierce, Miller, multivibrator-type

MOUNTING DATA

Crystal Holder: HC-17/U

Method of Mounting Crystal: Wire-mounted in metal holder.

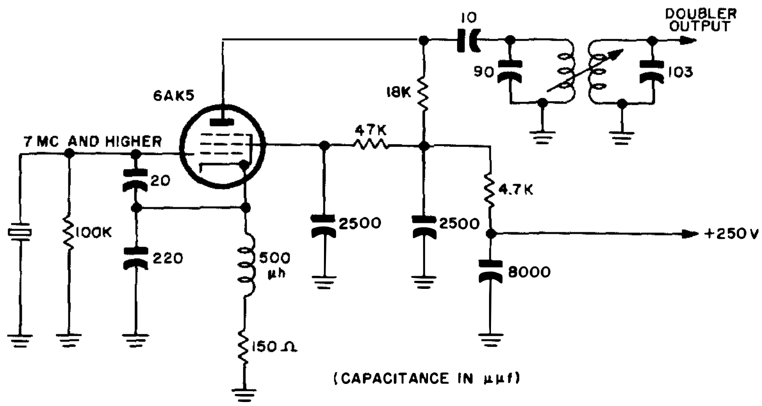


Figure 2-74. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-58/U

Dimensions and Marking: See figure 2-73. All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Special Application (Category 2)

Date of Status: 15 December 1955

Related Specifications, Standards, and Publications: See Appendix IV

Commercial Sources: See Appendix III

Remarks: Identical to CR-18/U except uses Holder HC-17/U (with larger pins) instead of HC-6/U.

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-25498 (USAF)

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50

Reference Standard Test Set:
Crystal Impedance Meter TS-330/TSM—800 to 14,999.999 kc
Crystal Impedance Meter TS-683/TSM—15,000 to 20,000 kc

Electrical Connection of Holder:
Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure:
800 to 14,999.999 kc: MS90167 (see paragraph 2-60 and MIL-C-3098B)
15,000 to 20,000 kc: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:
Permitted change in frequency:
±0.001% for units below 2000 kc
±0.0005% for units of 2000 kc and above
Permitted change in resonance (effective) resistance: Wire-mounted—±15% or 2 ohms, whichever is greater.

Aging Test: Not required

Tensile Strength Test (Minimum Requirements):
Not required

CRYSTAL UNIT CR-59/U

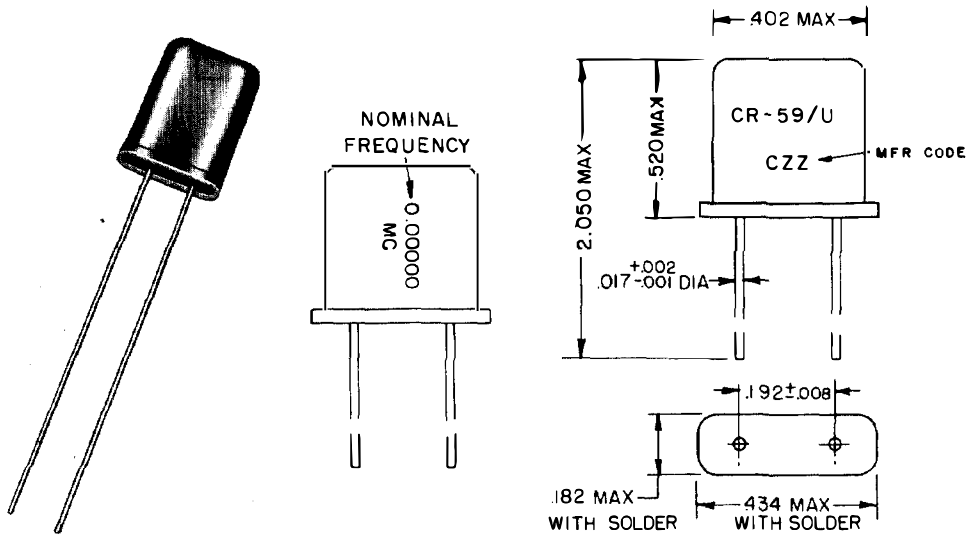


Figure 2-75. Crystal Unit CR-59/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, mounted in a metal holder and designed to operate at series resonance on the fifth harmonic of the fundamental frequency of the quartz plate. The crystal is intended to be mounted in a temperature-controlled oven.

RATED OPERATING CHARACTERISTICS

Frequency Range: 50.0 to 91.0 mc

Nominal Frequency Tolerance: ±0.002% at +85°C ±5°C

Frequency Deviation with Temperature: ±0.0005% from frequency measured at 85°C permitted over range of 80°C to 90°C

Operating Temperature Range: 85°C ±5°C

Operable Temperature Range: —55° to +90°C

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration: Fifth harmonic mode

Maximum Drive Level: 1.0 mw

Maximum Pin-to-Pin Capacitance: 7 μμf

Maximum Effective Resonance Resistance: 60 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118

TYPES OF CIRCUITS USED IN

Butler, transformer - coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-18/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-75. All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Special Application (Category 1)

Date of Status:

Related Specifications, Standards, and Publications: See Appendix IV

Commercial Sources: See Appendix III

Remarks:

Equipment Used In:

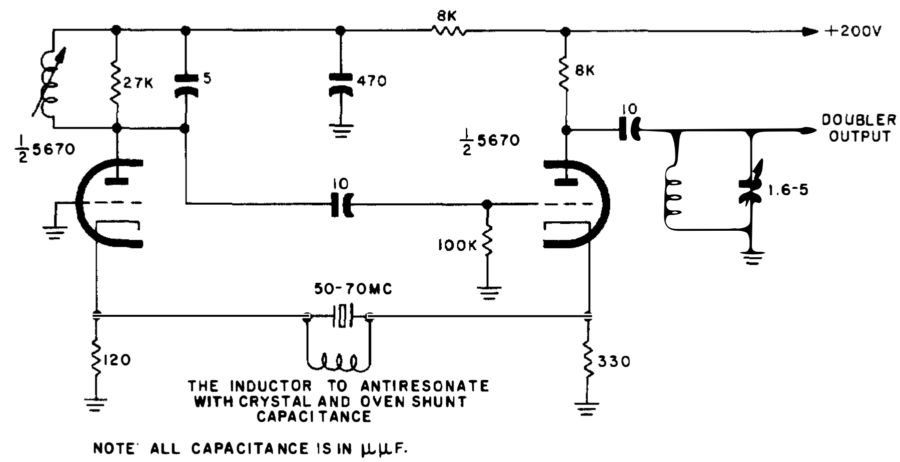


Figure 2-76. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-59/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-25709 (USAF)

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-60/U

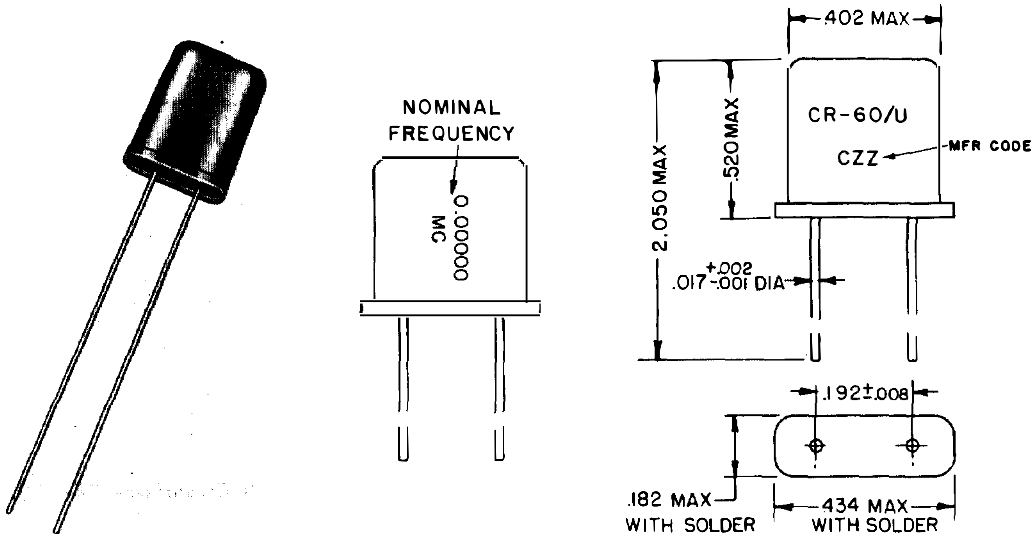


Figure 2-77. Crystal Unit CR-60/U

FUNCTIONAL DESCRIPTION

Metal-plated quartz plate, wire-mounted in a metal holder and designed to operate on the fundamental frequency of the quartz plate. Used as a medium-to-high-frequency control element in circuits which must maintain above average frequency stability in the absence of oven control, even when exposed to wide variation of temperature. The crystal unit is intended for operation at series resonance.

RATED OPERATING CHARACTERISTICS

Frequency Range: 7.0 to 20.0 mc

Nominal Frequency Tolerance: ±0.005% at all temperatures within the operating range

Frequency Deviation with Temperature: Permissible within limits of nominal frequency tolerance

Operating Temperature Range: —55° to +105°C

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration: Fundamental

Maximum Drive Level:

7.0 to 9.999999 mc (10 mw)

10.0 to 20.0 mc (5 mw)

Maximum Pin-to-Pin Capacitance: 7 $\mu\mu$f

Maximum Effective Resonance Resistance:

Frequency (mc)	*Resistance (ohms)*
7.0 to 9.999	30
10.0 to 20.000	25

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118

TYPES OF CIRCUITS USED IN

Butler, transformer-coupled, transitron, modified colpitts

MOUNTING DATA

Crystal Holder: HC-18/U

Method of Mounting Crystal: Wire-mounted in metal holder.

Dimensions and Marking: See figure 2-77. All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Special application (Category 1)

Date of Status:

Related Specifications, Standards, and Publications: See Appendix IV

Commercial Sources: See Appendix III

Remarks: Similar to CR-19/U except frequency range and size of holder.

Equipment Used In:

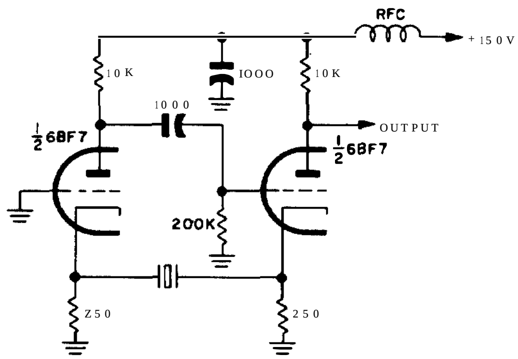


Figure 2-78. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-60/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-25710 (USAF)

Requirements and Procedures of Tests: See paragraphs 2-21 through 2-50

Reference Standard Test Set:

Frequency (mc)	*Test Set*
7.0 to 9.999	TS-330/TSM
10.0 to 20.0	TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: A

Drive Adjustment Procedure:

7.0 to 9.999 mc: MS90167 (see paragraph 2-60 and MIL-C-3098B)

10.0 to 20.0 mc: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15%

Aging Test: Not specified

Tensile Strength Test (Minimum Requirements): Not required

CRYSTAL UNIT CR-61/U

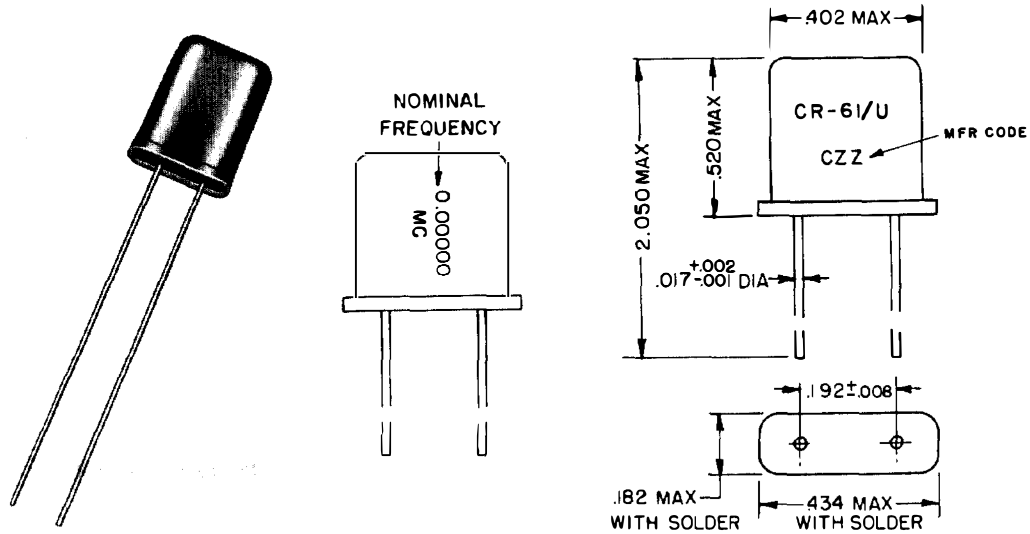


Figure 2-79. Crystal Unit CR-61/U

FUNCTIONAL DESCRIPTION

A metal-plated, quartz plate mounted in a metal holder and designed to operate at series resonance on the third mechanical overtone of the fundamental frequency of the quartz plate. The crystal unit is intended to be operated at a controlled temperature.

RATED OPERATING CHARACTERISTICS

Frequency Range: 17.0 to 61.0 mc

Nominal Frequency Tolerance: ±0.002% at 85°C

Frequency Deviation with Temperature: ±0.0005% from frequency measured at 85°C permitted over range of 80° to 90°C

Operating Temperature Range: 85°C ±5°C

Operable Temperature Range: —55° to +90°C

Resonance: Series

Load Capacitance: Not applicable

Harmonic of Quartz Vibration: Third harmonic mode

Maximum Drive Level:
17.0 to 24.999 mc (2mw)
25.0 to 61.0 mc (1mw)

Maximum Pin-to-Pin Capacitance: 7 $\mu\mu$f

Maximum Effective Resonance Resistance: 40 ohms

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element A, paragraph 1-112, figures 1-49, -112, -113, -115, -118

TYPES OF CIRCUITS USED IN

Transistor, Butler, transformer-coupled, capacitance-bridge, transitron, impedance-inverted

MOUNTING DATA

Crystal Holder: HC-18/U

Method of Mounting Crystal: Wire-mounted in metal holder

Dimensions and Marking: See figure 2-79. All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

LOGISTICAL DATA

USAF Stock No.: 2100-

Status: Special application (Category 1)

Date of Status: 13 March 1956

Related Specifications, Standards, and Publications: See Appendix IV

Commercial Sources: See Appendix III

Remarks:

Equipment Used In:

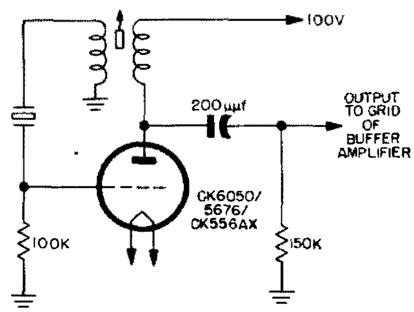


Figure 2-80. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-61/U

MILITARY STANDARD TEST DATA

Authority: Military Specification MIL-C-19374 (SHIPS), approved 13 March 1956

Requirements and Procedures of Tests: See paragraphs 2-21 to 2-50

Reference Standard Test Set: Crystal Impedance Meter TS-683/TSM

Electrical Connection of Holder: Holder grounded

Method of Measuring Frequency and Effective Resonance Resistance: B

Drive Adjustment Procedure: MS90168 (see paragraph 2-62 and MIL-C-3098B)

Shock and Vibration Test:

Permitted change in frequency: ±0.0005%

Permitted change in effective resonance resistance: ±15%

Aging Test:

Permitted change in frequency: ±0.001%

Tensile Strength Test: Not required

CRYSTAL UNIT CR- /U

(For addenda)

Figure 2-81. Crystal Unit CR- /U

FUNCTIONAL DESCRIPTION

Frequency (kc) *Resistance (ohms)*

RATED OPERATING CHARACTERISTICS

Frequency Range:

Nominal Frequency Tolerance:

Frequency Deviation with Temperature:

Operating Temperature Range:

Operable Temperature Range:

Resonance:

Load Capacitance:

Harmonic of Quartz Vibration:

Maximum Drive Level:

Maximum Pin-to-Pin Capacitance:

Maximum Effective Resonance Resistance:

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element , paragraph 1- , figure 1-

TYPES OF CIRCUITS USED IN

MOUNTING DATA

Crystal Holder:

Method of Mounting Crystal:

Dimensions and Marking: See figure 2- (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

Figure 2-82. Schematic diagram of typical oscillator designed for use with Crystal Unit CR- /U

LOGISTICAL DATA

USAF Stock No.: 2100-

Status:

Date of Status:

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks:

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority:

Requirements and Procedures of Tests: See paragraphs through

Reference Standard Test Set: Crystal Impedance Meter

Electrical Connection of Holder:

Method of Measuring Frequency and Effective Resonance Resistance:

Drive Adjustment Procedure:

Shock and Vibration Test:

Permitted change in frequency:

Permitted change in effective resonance resistance:

Aging Test:

Permitted change in frequency:

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*

CRYSTAL UNIT CR- /U

(For addenda)

Figure 2-83. Crystal Unit CR- /U

FUNCTIONAL DESCRIPTION

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*

RATED OPERATING CHARACTERISTICS

Frequency Range:

Nominal Frequency Tolerance:

Frequency Deviation with Temperature:

Operating Temperature Range:

Operable Temperature Range:

Resonance:

Load Capacitance:

Harmonic of Quartz Vibration:

Maximum Drive Level:

Maximum Pin-to-Pin Capacitance:

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element , paragraph 1- , figure 1-

TYPES OF CIRCUITS USED IN

MOUNTING DATA

Crystal Holder:
Method of Mounting Crystal:
Dimensions and Marking: See figure 2- (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

Figure 2-84. Schematic diagram of typical oscillator designed for use with Crystal Unit CR- /U

LOGISTICAL DATA

USAF Stock No.: 2100-

Status:

Date of Status:

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks:

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority:

Requirements and Procedures of Tests: See paragraphs through

Reference Standard Test Set: Crystal Impedance Meter

Electrical Connection of Holder:

Method of Measuring Frequency and Effective Resonance Resistance:

Drive Adjustment Procedure:

Shock and Vibration Test:

Permitted change in frequency:

Permitted change in effective resonance resistance:

Aging Test:

Permitted change in frequency:

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*

CRYSTAL UNIT CR- /U

(For addenda)

Figure 2-85. Crystal Unit CR- /U

FUNCTIONAL DESCRIPTION

RATED OPERATING CHARACTERISTICS

Frequency Range:

Nominal Frequency Tolerance:

Frequency Deviation with Temperature:

Operating Temperature Range:

Operable Temperature Range:

Resonance:

Load Capacitance:

Harmonic of Quartz Vibration:

Maximum Drive Level:

Maximum Pin-to-Pin Capacitance:

Maximum Effective Resonance Resistance:

Frequency (kc)	*Resistance (ohms)*

PERFORMANCE CHARACTERISTICS OF NORMAL CRYSTAL ELEMENT

See characteristics of element , paragraph 1- , figure 1-

TYPES OF CIRCUITS USED IN

MOUNTING DATA

Crystal Holder:
Method of Mounting Crystal:
Dimensions and Marking: See figure 2- (B). All dimensions in inches. Unless otherwise specified, tolerances are ±0.005 in. on decimals.

Figure 2-86. Schematic diagram of typical oscillator designed for use with Crystal Unit CR-   /U

LOGISTICAL DATA

USAF Stock No.: 2100-

Status:

Date of Status:

Related Specifications, Standards, and Publications: See Appendix IV.

Commercial Sources: See Appendix III.

Remarks:

Equipment Used In:

MILITARY STANDARD TEST DATA

Authority:

Requirements and Procedures of Tests: See paragraphs through

Reference Standard Test Set: Crystal Impedance Meter

Electrical Connection of Holder:

Method of Measuring Frequency and Effective Resonance Resistance:

Drive Adjustment Procedure:

Shock and Vibration Test:

Permitted change in frequency:

Permitted change in effective resonance resistance:

Aging Test:

Permitted change in frequency:

Tensile Strength Test (Minimum Requirements):

Frequency (kc)	*Grams*

GROUP II

CRYSTAL UNITS CURRENTLY IN MILITARY SERVICE BUT NOT RECOMMENDED FOR USE IN EQUIPMENTS OF NEW DESIGN

The crystal units included in Group II are those currently being used by the United States Air Force, but which are not preferred for use in equipments of new design. Where available, data sheets are included giving the quality control test specifications of the individual units. For illustrations of the principal holders, see Crystal Holders—Group II in Section III.

TECHNICAL DATA CHART FOR GROUP-II CRYSTAL UNITS

USAF Stock Number 2100-[a]	*Nomenclature*	*Crystal Holder*	*Equipment Used In*	*Crystal Spec*	*Holder Spec*
2x4-	Crystal Unit CR-1A/AR B C	CR-1A/AR	AN/ARC-7, AN/ARM-1, BC-517, BC-624, BC-625, BC-640, BC-1158, R-77/ARC-3, R-89 ( )/ARN-5A, R-150A/CRW-7	MIL-C-16B	MIL-C-16B
2x5-	Crystal Unit	FT-249			171-148B
2x7-	Crystal Unit CR-6B/U	FT-243	R-19/TRC-1	MIL-C-10405	72-119
2x8-	RCA MI-8412	MI-8412	RCA Model AVT-15, RCA Model AVT-112	MIL-C-10405	
2x10-	Crystal Unit	FT-243	BC-745; SCR-511		72-119
2x11-	Crystal Unit	FT-243	BC-745; SCR-511		72-119
2x12-	Crystal Unit	FT-171-B	BC-610; SCR-299, 399, 499, 699	MIL-C-10405	
2x13-	Crystal Unit CR-4B/U	FT-241-A	AN/TRC-1, -3, -4		
2x14-	Crystal Unit	FT-243			72-119
2x15-5000	Crystal Unit CR-10B/U	FT-243	R-48/TRC-8, I-222-A		72-119
2x16-80.86	Valpey Crystal Part XLST		AN/APS-15 Rec.		
2x17-	Crystal Unit (1st Osc)	FT-171B	FM-1498-1505 (Link)	MIL-C-10405	72-119
2x17-	Crystal Unit (2nd Osc)	FT-243	FM-1498-1505 (Link)	MIL-C-10405	72-119
2x18-	Crystal Unit	FT-171-B/ FT-243	Link Xmtr 1498	MIL-C-10405	72-119
2x20-	Crystal Unit	AVA-10 or 601	RCA Model AVT-15, RCA Model AVT-112	MIL-C-10405	72-119
2x23-	Crystal Unit (Collins 1C)		Collins 32-RA	MIL-C-10405	
2x24-163.94	Crystal Units (Bliley MC-72) (James Knights F)		I-223-A		
2x25-455	Crystal Unit (Bliley CF-6) (Hallicrafters 19A123)		SX-28, R-45/ARR-7		

[a] See paragraph 2-59.

Freq Range (mc)	*Freq Tolerance (±%)*	*Operating Temperature Range (°C)*	*Base or Terminal Connections*	*Physical Dimensions (In.)*		
				High	*Wide*	*Thick*
2.0—15.0	0.02	−55° to +90°	2 pins, 5/8 in. lg, 1/8 in. dia, 1/2 in. c to c	1 7/8 •	1 1/8	7/16
			3 pins, 0.125 in. dia, 1/2 in. lg	2 11/16	1 7/16	1 3/8
2.0—10.0	0.02	−40° to +70°	2 pins, 13/32 in. lg, 3/32 in. dia, 1/2 in. c to c	1 19/32	13/16	13/32
2.0—5.8	0.015	0° to +70°	2 banana pins, 13/16 in. lg, 0.85 in. c to c	1 3/32	1 1/2	13/16
3.0—6.0			Same as 2x7			
3.465 6.455			Same as 2x7			
2.0—6.0	0.02	0° to +70°	2 banana pins, 25/32 in. lg, 25/32 in. c to c	2 7/8	1 1/2	25/32
70.0—99.9	0.02	−40° to +70°	2 pins, 7/16 in. lg, 5/64 in. dia, 1/2 in. c to c	1 1/2	1 1/8	7/16
2.88—4.3			Same as 2x7			
5.0	250 cps	−40° to +70°	Same as 2x7			
0.08086			NL			
6.25—10.5	0.02	0° to +70°	Same as 2x12			
6.456	0.02	0° to +70°	Same as 2x12			
2.187—2.125	0.02	0° to +70°	Same as 2x12 or 2x7			
1.715—7.5	0.015	0° to +70°	2 banana pins, 3/4 in. lg, 0.850 in. c to c	2 7/8	1 1/2	15/16
1.5—3.75	0.015	0° to +50°	5-pin, 1/2 in. lg, 1/8 in. dia	1 7/8	1 1/2	1 1/8
0.16394			2 banana pins, 1/2 in. lg, 3/4 in. c to c	1 3/8	1 1/8	9/16
0.455			NL			

TECHNICAL DATA CHART FOR GROUP-II CRYSTAL UNITS—*Continued*

USAF Stock Number 2100-[a]	*Nomenclature*	*Crystal Holder*	*Equipment Used In*	*Crystal Spec*	*Holder Spec*
2x27-465	Crystal Unit	RCA-MI-19453 Hammarlund SA-178	AN/GRR-2, BC-1004, AN/MRC-3, -4		
2x28-	Crystal Unit	HC-1/U	AN/URC-2, AN/FRC-6	MIL-C-10404	
2x29-	Crystal Unit	FT-249	SCR-281, BC-441	MIL-C-10404	
2x34-455	Crystal Unit (Majestic Dwg 29E6)		BC-969-A, SCR-614-A		
2x35-	Crystal Unit CR-5B/U	FT-243	BC-611, SCR-536	MIL-C-239B	72-119
2x36-	Crystal Unit CR-5B/U	FT-243	BC-1000, SCR-300	MIL-C-239B	72-119
2x37-	Crystal Unit (Bliley AR-3)		RC-65		
2x38-	Crystal Unit	FT-249	BC-1271-A, Wilcox 98A	MIL-C-10405	
2x39-	Crystal Unit	FT-164	RC-52E, BC-797, SCR-641		
2x40-	Crystal Unit (Monitor Piezo 8), (Bendix 3947)	Special	SCR-638, Bendix FC-3006, 3103-24, 3806-24		
2x43-	Crystal Unit (Bliley MO-2)		Hallicrafters HT-4, -9, T-811/VRC-4		
2x48-	Crystal Unit DC-8		BC-225, -338, -352, -353, -457, -458, -459, -695, -696, SCR-240, 261, 264, -274N		
2x50-	Crystal Unit DC-20	FT-243	BC-733, RC-103	MIL-C-10404	72-119
2x53-	Crystal Unit CR-8B/U	FT-243	RT-12/TRC-2, BC-1306, RT-77/GRC-9	MIL-C-10405	72-119
2x54-12500	Crystal Unit (Bliley MO-2)	Bliley MC-5 or -7	BC-376		
2x55-	Crystal Unit CR-10/U	FT-243		MIL-C-10405	72-119
2x58-	Crystal Unit	FT-243	BC-659, SCR-609, -610	MIL-C-10405	72-119
2x60-	Crystal Unit (RCA TMV-129-B)		RCA transmitter 1-K		
2x61-	Crystal Unit	RCA-AVA-53-A	RCA Models AVT-15, -112, ARV-20	MIL-C-10405	
2x62-327.8	Crystal Unit (WECOD-168342)		TS-102/AP		
2x63-	Crystal Unit (WECO5B)		Northern Elec. AT-7		
2x64-1	Crystal Unit				
2x65-	Crystal Unit	FT-243	R-57/ARN-5	MIL-C-16B	72-119
2x66-	Crystal Unit	FT-243	BC-1209, SCR-583 (Xmtr only)		72-119
2x67-	Crystal Unit	FT-243	BC-1209, SCR-583 (Rec only)		72-119
2x68-	Crystal Unit DC-34	FT-171-B	BC-669, SCR-543 (Xmtr only)		

[a] See paragraph 2-59.

Freq Range (mc)	*Freq Tolerance (±%)*	*Operating Temperature Range (°C)*	*Base or Terminal Connections*	*Physical Dimensions (In.)*		
				High	*Wide*	*Thick*
0.465			NL			
0.9375—8.2	0.01	−55° to +90°	2 pins, 9/16 in. lg, 1/8 in. dia, 3/4 in. c to c	1 3/32	1 1/8	1 1/8
1.6—3.0	0.01	0° to +50°	Same as 2x5			
0.455			NL			
2.0—10.0	0.02	−55° to +90°	Same as 2x7			
4.3 (Xmtr) 6.815 (Rec)	0.02	−55° to +90°	Same as 2x7			
30—40			5-pin, 1/2 in. lg, 1/8 in. dia	2	1 9/16	1 3/16
4.8375 7.458611	0.01	0° to +70°	Same as 2x5			
1.7—9.0			Term. pin on each side, 1/2 in. lg, 5/16 in. dia	1 5/16	2 5/16 (dia)	
			Octal	1 1/4	1 1/2 (dia)	
1.7—7.5	0.02	0° to +50°	2 pins, 9/16 in. lg, 1/8 in. dia, 3/4 in. c to c	1 3/16	1 3/8 (dia)	
3.0—8.0			Octal	2 13/32	1 9/32 (dia)	
5.633— 5.744444	0.02	−40° to +85°	Same as 2x7			
1.0—10.0	0.02	−40° to +70°	Same as 2x7			
12.5			Same as 2x43			
5.0	0.005	−40° to +70°	Same as 2x7			
5.675—8.650	0.02	−40° to +70°	Same as 2x7			
0.325—3.0	10 cps	+60°	6-pin, 3/4 in. lg, 5/32 in. dia	4	2 1/2	1 5/16
1.75—7.5	0.015	−40° to +55°	2 banana pins, 3/4 in. lg, 0.85 in. c to c	1 7/16	1 3/4	9/16
0.3278			NL			
			3-pin, 37/64 in. lg, 5/32 in. dia	2 27/64	1 19/32	3/16
0.375 and 0.5			3-pin, 9/16 in. lg, 5/32 in. dia	1 27/32	1 19/32	1 3/16
6.497917 6.547917	0.02	−40° to +70°	Same as 2x7			
			Same as 2x7			
			Same as 2x7			
			Same as 2x12			

TECHNICAL DATA CHART FOR GROUP-II CRYSTAL UNITS—*Continued*

USAF Stock Number 2100-[a]	*Nomenclature*	*Crystal Holder*	*Equipment Used In*	*Crystal Spec*	*Holder Spec*
2x69-	Crystal Unit DC-35	FT-171-B	BC-669, SCR-543 (Rec only)		
2x70-	Crystal Unit	FT-164	BC-400-( )		
2x70-4166.67	Crystal Unit	FT-164	BC-400-B thru G		
2x73-186.30	Crystal Unit (James Knights Type F)		BC-1267, I-233-A, TS-293/CPA-5, AN/CPX-1, -2		
2x74-	Crystal Unit	FT-241-A	BC-604, SCR-508, -528		
2x75-	Crystal Unit	FT-249	AN/FRR-3		
2x75-462.45	Crystal Unit				
2x76-	Crystal Unit	FT-249	Temco Xmtr 250 GSC		
2x77-	Crystal Unit	FT-171-B	SCR-298, Link FM Model 11-U-F	MIL-C-10405	
2x78-	Crystal Unit	FT-171-B			
2x79-	Crystal Unit	FT-249	BC-329-N	MIL-C-10405	
2x81-	Crystal Unit	FT-171B	R-114/VRC-4		
2x83-81.95	Crystal Unit (GE TYPE 53)		BC-1602, SCR-584		
2x84-	Crystal Unit	FT-171-B	BC-325, SCR-197-F		
2x86-1	Crystal Unit (WECOD-151584)		R-55/ARQ-9		
2x87-	Crystal Unit	FT-164	Fed T & T TLC, TSI		
2x89-100	Crystal Unit (RCA VC-5KS)	RCA VC-5-KL	BC-1184, SCR-722, ID-6/APN-4		
2x90-470	Crystal Unit DC-6		SCR-177, -185, -188, -193, -209, -210, -287		
2x91-	Crystal Unit DC-17A		BC-751, AN/MRN-1		
2x95-245.895	Crystal Unit DC-21				
2x95-	Crystal Unit DC-13 and DC-14		BC-303, SCR-241		
2x96-	Crystal Unit	FT-164	T-65/CRN-11, AN/CRN-20, BC-901, RC-139		
2x98-	Crystal Unit	FT-241-A	BC-684, SCR-608		
2x100-100	Crystal Unit (Bliley SMC-100)		Hallicrafters HT-7		
2x103-93.12	Crystal Unit (GE Dwg K-56J906)		TS-177/CPS-1, TS-241/CPS-5		
2x104-100	Crystal Unit (RCA VC-5-M)		R-65/APN-9		
2x105-200	Crystal Unit CR-2B/U	FT-241/A	AN/ART-13		
2x106-	Crystal Unit	FT-249	BC-401	MIL-C-10405	

[a] See paragraph 2-59.

Freq Range (mc)	*Freq Tolerance (±%)*	*Operating Temperature Range (°C)*	*Base or Terminal Connections*	*Physical Dimensions (In.)*		
				High	*Wide*	*Thick*
			Same as 2x12			
4.116 and 4.687	0.01	−15° to +50°	Same as 2x39			
4.16667	0.01	−15° to +50°	NL			
0.1863			NL			
			Same as 2x13			
1.4—3.8	0.01	+45° to +55°	Same as 2x5			
			NL			
			Same as 2x5			
3.125—4.395	0.02	0° to +70°	Same as 2x12			
1.875—2.875	0.02	−40° to +70°	NL			
0.2—0.4	0.01	−10° to +50°	Same as 2x5			
1.175—8.175			Same as 2x12			
			Octal, 2-pin, 35/64 in. lg, 7/16 in. dia	3 5/32	1 5/16 (dia)	
0.75—2.25	0.02	0° to −70°	Same as 2x12			
5.0 and 5.455				1 5/16	1 11/32 (dia)	
0.125—0.195 0.3—0.4			Same as 2x39			
0.100	+85 to −35 cps	−40° to +70°	3-pin, 1/2 in. lg, 5/32 in. dia	2 3/16	1 9/16	1 3/16
0.470			NL			
6.016, 6.038, 6.061, 6.083, 6.105, 6.127, 0.245895			Octal	2 13/32	1 9/32 (dia)	
0.245895			Same as 2x89-100			
DC-13: 0.201 DC-14: 0.219			Octal	2 7/16	1 5/16 (dia)	
0.2—0.4	0.01	−15° to +50°	Same as 2x39			
			Same as 2x13			
0.100 and 1.000			2 solder lugs	1 3/8	1 3/8	23/32
0.09312			Octal	13/32	1 9/16	1 13/16
			3-pin, 39/64 in. lg, 0.156 in. dia	2 47/64	1 19/32	1 13/16
0.2	18 cps	−40° to +70°	Same as 2x13			
1.0—4.525	0.01	0° to +50°	Same as 2x5			

TECHNICAL DATA CHART FOR GROUP-II CRYSTAL UNITS—*Continued*

USAF Stock Number 2100-[a]	*Nomenclature*	*Crystal Holder*	*Equipment Used In*	*Crystal Spec*	*Holder Spec*
2x107-	Crystal Unit	FT-249, AA-9E, MX-9E	Bendix RA-10, RTA-1, AN/ARC-9	MIL-C-10405	
2x111-98.356	Crystal Unit DC-22-A		BC-788, SCR-718		
2x112-100	Crystal Unit (Philco 455-1040) (RCA VC-5-KS)		BC-622		
2x113-13545	Crystal Unit (WECO Dwg D-152497)		R-102/ARQ-9		
2x116-300	Crystal Unit (WECO D-168342)		SCR-545-A		
2x121-	Crystal Unit	FT-164	Fed Tel & Rad CAA 293		
2x122-18.626	Crystal Unit (WECO D-169112)		ID-56/APQ-7		
2x124-	Crystal Unit	Valpey CM.1, Bliley MC-74	Comm. Co. 150C		
2x125-	Crystal Unit	FT-171-B	JT Rad Model 350-A (Rec)		
2x127-	Crystal Unit	FT-171-B	JT Rad Model 350-A (Xmtr)		
2x131-	Crystal Unit	FT-249	T-4/FRC		
2x133-	Crystal Unit	FT-249	Wilcox F3	MIL-C-10405	
2x136-12500	Crystal Unit	FT-243	BC-376-H		72-119
2x137-	Crystal Unit	FT-249, MX-9G, M-9G	Wilcox 96-200		
2x138-100	Crystal Unit (Bliley BC-46RS)		TS-308/U		
2x141-93.109	Crystal Unit (RCA Type VC-5M)	RCA Type VC-5-K	ID-17/APN-3		
2x142-80.86	Crystal Unit (Bliley FM-6)		TS-100/AP		
2x144-	Crystal Unit	FT-249	Navy Model TCS		
2x147R-	Crystal Unit	FT-243	BC-721 (Rec), SCR-585		72-119
2x147T-	Crystal Unit	FT-243	BC-721, SCR-585 (Xmtr)		72-119
2x148-	Crystal Unit	FT-171	Link FMTR-25, -35, UFS-50		
2x149-	Crystal Unit	FT-164	BC-329-A		
2x150-93.109	Crystal Unit (RCA Type TMV-129E)		ID-18/CPN-2		
2x154-300.060	Crystal Unit (WECO 8A)		WECO 23AA, 221B		
2x155-300	Crystal Unit (WECO 8B)				
2x156-300.050	Crystal Unit (WECO 8C)				
2x157-	Crystal Unit	FT-243	TS-233/TPN-2		72-119
2x163-1.81818	Crystal Unit CR-11/U		TS-251/UP		
2x163-1817.44	Crystal Unit CR-11/U		WECO D-170130		
2x167-	Crystal Unit	FT-164	BC-446, BC-467, SCR-277		
2x168-	Crystal Unit	FT-164	BC-447		

[a] See paragraph 2-59.

Freq Range (mc)	*Freq Tolerance (±%)*	*Operating Temperature Range (°C)*	*Base or Terminal Connections*	*Physical Dimensions (In.)*		
				High	*Wide*	*Thick*
2.5—7.0	0.015	−40° to +55°	Same as 2x5			
0.098356	0.05	−10° to +50°	Same as 2x89-100			
0.1				2 3/32	1 19/32	1 3/16
13.545			2-pin, 1/2 in. lg, 1/8 in. dia	1 13/64	1 1/8	7/16
0.3			Octal	3	1 1/4 (dia)	
0.1—10.0			Same as 2x39			
0.018626			Octal	4	1 1/4 (dia)	
			NL			
			Same as 2x12			
			Same as 2x12			
2.0—6.0	0.02	0° to +70°	Same as 2x5			
1.0—6.0	0.02	0° to +60°	Same as 2x5			
12.5			Same as 2x7			
0.125—0.525	0.01	0° to +70°	Same as 2x5			
0.100		+50°	5-pin, electrode pin, connection on side	2 9/16	2 1/4 (dia)	
0.093109	10 cps	−54° to +70°	3-pin, 7/8 in. lg, 5/32 in. dia	2 3/8	1 5/8	1
0.08086			2-pin, 3/4 in. lg, 1/8 in. dia, 3/4 in. c to c	1 21/32	1 3/4 (dia)	
			Same as 2x5			
3.955—6.455			Same as 2x7			
3.5—6.0			Same as 2x7			
0.9375—1.25	0.02	0° to +70°	Same as 2x12			
0.2—0.41	0.02	−15° to +50°	Same as 2x39			
0.093109	0.01	0° to +55°	6-pin, 3/4 in. lg, 5/32 in. dia	4	2 1/2	1 15/16
0.300060			Octal	2 5/8	1 1/4 (dia)	
0.300			Same as 2x154-300.060			
0.300050			Same as 2x154-300.060			
6.6875—7.3125			Same as 2x7			
0.00181818			NL			
1.81744			NL			
0.2—0.4	0.01	−10° to +60°	Same as 2x39			
1.5—5.0			Same as 2x39			

TECHNICAL DATA CHART FOR GROUP-II CRYSTAL UNITS—*Continued*

USAF Stock Number 2100-[a]	*Nomenclature*	*Crystal Holder*	*Equipment Used In*	*Crystal Spec*	*Holder Spec*
3x172-4495	Crystal Unit DC-10		BC-230, BC-430		
2x173-	Crystal Unit	FT-171-B	Fisher Research Rec		
2x174-	Crystal Unit	FT-171-B	Fisher Research Xmtr TS-25-3	MIL-C-10405	
2x174R-	Crystal Unit	FT-171-B	R-114/VRC-4	MIL-C-10405	
2x175-409.5	Crystal Unit (James Knights Type IF-6Y-101)		TS-126/AP		
2x177-2	Crystal Unit CR-8/U		R-122/APN-12		
2x180-	Crystal Unit	FT-249	Bendix Xmtr TA-6A	MIL-C-10405	
2x181-80.86	Crystal Unit (WECO D-166339)		AN/APQ-13		
2x186R-	Crystal Unit	FT-243	BC-611 (Rec)	MIL-C-239B	72-119
2x186T-	Crystal Unit	FT-243	BC-611 (Xmtr)	MIL-C-239B	72-119
2x187-1.617	Crystal Unit (WECO D-170609)		MD-57/APS-22		
2x188-	Crystal Unit	FT-240	Tempco Xmtr 250-G		
2x191R-	Crystal Unit	Bliley MC-7	BC-348-R		
2x192C-	Crystal Unit CR-3B/U	FT-241-A	BC-506, SCR-508, SCR-528, BC-604, SCR-608	TB SIG 201	
2x204-100	Crystal Unit (RCA-TMV-129G)		AN/CPN-11, -11A, -11B, -12, -12A, -12B		
2x212-80.867	Crystal Unit		AN/CPS-6B		
2x600-	Crystal Unit CR-5/U	FT-243	BC-721	MIL-C-239B	72-119
2x602-	Crystal Unit	FT-249	AN/FRR-3A	MIL-C-10405	
2x602-462.45	Crystal Unit	FT-249	AN/FRR-3A	MIL-C-10405	
2x604-	Crystal Unit	RCA-AVA-53	RCA-AVR-20A		
2x606-	Crystal Unit	AVA-10-D	RCA-AVT-7 (Xmtr)	MIL-C-10405	
2x609-	Crystal Unit	FT-164	BC-330		
2x610-4166.67	Crystal Unit	FT-249	BC-400-H		
2x611-	Crystal Unit	FT-249	BC-460-A thru C, BC-401-( )		
2x634-	Improvement Kit MC-531	HC-1/U		MIL-C-10405	
2x635-	Crystal Unit CR-1/AR	FT-249	O-5/FR	MIL-C-10405	1.8
2x680-	Crystal Unit CR-7/U	FT-164	MAR Receiver		
NL-00019	Crystal Unit	FT-164	BC-329-H		

a See paragraph 2-59.

Freq Range (mc)	*Freq Tolerance (±%)*	*Operating Temperature Range (°C)*	*Base or Terminal Connections*	*Physical Dimensions (In.)*		
				High	*Wide*	*Thick*
4.495			NL			
2.0—8.0			Same as 2x12			
2.0—8.0	0.01	0° to +70°	Same as 2x12			
1.175—9.175		0° to +70°	Same as 2x12			
0.4095			2 screw-type terminals on each side	1	½	13/32
15—52			Wire terminals	1 1/16	9/16 (dia)	
2.8—6.0	0.15	−40° to +55°	Same as 2x5			
0.08096			Octal	1	1⅛ (dia)	
3.5—6.455	0.02	−40° to +70°	Same as 2x7			
3.5—6.235	0.02	−40° to +70°	Same as 2x7			
0.001617			Octal	3⅞	1¼ (dia)	
			Same as 2x5			
			2-pin, 9/16 in. lg, ⅛ in. dia, .334 in. c to c	1 15/16	1⅛	19/32
0.3—0.6	0.02	−40° to +70°	Same as 2x13			
0.1			6-pin, ¾ in. lg, 5/32 in. dia	4	2½	2½
0.080867			Octal	2 11/16	63/64 (dia)	
2.0—10.0	0.02	−40° to +70°	Same as 2x7			
1.4—3.8	0.01	+45° to +55°	Same as 2x5			
0.46245	0.01	+45° to +55°	Same as 2x5			
2.755—7.155	0.05	−40° to +55°	2 banana pins, .85 in. c to c	1¾	1 7/16	9/16
2.5—6.7	0.015	0° to +70°	Same as 2x20			
0.19—0.40	0.01	−15° to +50°	Same as 2x39			
4.16667	0.01	−15° to +50°	Same as 2x5			
1.0—6.0	0.01	0° to +50°	Same as 2x5			
1.956—6.830	0.005	0° to +60°	NL			
1.8—5.8	0.01	+45° to +60°	Same as 2x5			
0.29—0.40	0.02	−15° to +60°	Same as 2x39			
0.29—0.40	0.02	−15° to +60°	Same as 2x39			

RELATED MILITARY-SPECIFICATION INFORMATION

EXPLANATION OF MILITARY STANDARD TERMS USED IN DESCRIPTIONS OF CRYSTAL UNITS

Aging Test *(See paragraph 2-32)*

Authority

2-2. Serial numbers and dates of the military publications which prescribe the military specifications and military standards for the crystal unit being described.

Bonding Requirements *(See paragraph 2-22)*

Corrosion Test *(See paragraph 2-33)*

Crystal Holder

2-3. All crystal holders specified for Military-Standard crystal units must conform with Military Specification MIL-H-10056( ). A complete description of each standard holder is to be found in Section III of this manual.

Date of Status

2-4. Date of approval of the military status classification by the appropriate authority as prescribed by the applicable regulations of the Army, Navy, and Air Force.

Delivery Requirements *(See paragraphs 2-49 and 2-50)*

Dimensions and Markings

2-5. Illustrated and largely self-explanatory. Unless otherwise specified, the marking includes only the type number, nominal frequency, and manufacturer's code-designating letters. (See paragraph 2-26 for additional marking requirements.)

Drive Adjustment Procedure

2-6. Method to be used, as prescribed by the applicable Military Standard, in obtaining the correct level of crystal drive when testing the crystal unit with the specified CI meter. See paragraph 2-60.

Drop Test *(See paragraph 2-34)*

Effective Resistance Test at Second Level of Drive *(See paragraph 2-35)*

Electrical Connection of Holder

2-7. States whether the cover of a metal crystal holder is to be grounded or not when the crystal unit is connected in its standard test circuit. Not applicable in the case of plastic holders.

Electrical Connection Requirements Inside Holder *(See paragraph 2-24)*

Etching Requirements *(See paragraph 2-25)*

Fabrication Requirements *(See paragraphs 2-22 through 2-30)*

Frequency and Effective Resistance Test *(See paragraphs 2-31 and 2-36)*

Frequency Deviation with Temperature

2-8. As an additional permissible deviation, distinct from the nominal frequency tolerance, it is applicable in the case of crystal units whose nominal frequency tolerance is specified for a given fixed temperature only, rather than for any temperature within the operating range. The item then specifies the maximum additional variation in frequency that is permissible when the temperature is varied from the fixed reference point to any other temperature in the operating temperature range. Since this method is normally used only when the crystal unit is designed to operate at oven temperatures, where the operating range is narrow and presumably coincides with the zero-temperature-coefficient region of the crystal element, the design engineer is assured that once an oven-mounted crystal unit is in operation, any changes in its frequency due to reasonable changes in the oven temperature will be extremely small even though the overall nominal frequency tolerance from one crystal unit to the next is relatively large.

Frequency Range

2-9. Self-explanatory, except that it should not be assumed that crystal units can always readily be obtained at any desired frequency within the given range. The quickest, most reliable, and least expensive approach is to select a frequency at which the desired type of crystal unit is already available. If this is not possible, the next best approach is to select a frequency at which the crystal unit, although not currently available, has been available in the past. Finally, if it is necessary to fabricate a crystal unit at a heretofore untested frequency, the greatest probability of least delay and expense in the research and developmental stage is to select a frequency as close as possible to other frequencies now available in the desired type of Military Standard crystal unit. Occasionally, it may be found that the fabrication techniques of one manufacturer are more conducive to superior crystal units within one band of the frequency range, whereas another manufacturer fabricates the same type of crystal unit more reliably within another band. In any event, before a new untested frequency is decided upon, the design engineer should consult one or more of the manufacturers of the crystal unit under consideration.

Frequency Range Abbreviations

2-10. VLF (very low frequency) : less than 30 kc.
LF (low frequency) : 30 to 300 kc.
MF (medium frequency) : 300 to 3000 kc.
HF (high frequency) : 3 to 30 mc.
VHF (very high frequency) : 30 to 300 mc.

Functional Description

2-11. Provides summary of general physical and operational features of crystal unit, such as the type of mounting, operating harmonic, frequency range, frequency tolerance, temperature range, and mode of circuit operation.

Glass Seal Inspection *(See paragraph 2-37)*

Harmonic of Quartz Vibration

2-12. Mechanical harmonic of crystal element for which the military test specifications are applicable. Where a harmonic mode higher than the fundamental is specified, this should not be construed to mean that the crystal unit is more readily excited at the overtone than at the fundamental frequency, so that the desired harmonic can be obtained in an untuned type of oscillator.

Immersion Test *(See paragraph 2-38)*

Insulation Resistance Test *(See paragraph 2-39)*

Internal Inspection *(See paragraph 2-40)*

Leakage *(See paragraph 2-40a)*

Load Capacitance *(See paragraph 2-56)*

Marking Requirements *(See paragraph 2-26)*

Maximum Capacitance (Pin-to-Pin)

2-13. Maximum permissible electrostatic capacitance across the crystal-unit electrodes, as measured at the pin connections at a frequency lower than the fundamental of the crystal unit, where the unit shows no response other than that of a fixed capacitance.

Maximum Drive Level *(See paragraph 2-55)*

Maximum Effective Resonance Resistance

2-14. Maximum permissible effective resistance of crystal unit when measured at the specified test resonance and harmonic mode using the specified CI meter and drive adjustment procedure. For series-mode crystal units, the maximum effective resistance is the maximum permissible resonance impedance of the unit and, except at the very highest frequencies, is very nearly equal to an equivalent maximum permissible series-arm resistance. For parallel-mode crystal units, the maximum effective resistance is equal to the maximum permissible resistive component when the crystal impedance is represented as an equivalent resistance and reactance in series, at the exact frequency at which the reactive component is resonant with the test load capacitance.

Method A *(See paragraph 2-36a)*

Method B *(See paragraph 2-36b)*

Method of Measuring Frequency and Effective Resonance Resistance

2-15. The crystal unit is tested for frequency and effective resistance over the operating temperature range in accordance with either method A or method B. In general, method A, which sets minimum and maximum limits for the rate of temperature change, is specified for the smaller rectangular-shaped crystal units that are not intended to be operated in temperature-controlled compartments; otherwise, method B, which sets no limiting rate of temperature change, is specified.

Method of Mounting Crystal

2-16. Only two broad classifications of mounting methods are specified in the Military Standards for quartz crystal units: *pressure mounting* and *metal-plated, wire mounting.* The pressure-mounted method embraces all the sandwich and air-gap mounts except those of the gravity type, and also includes all those mounts having metal-plated crystals held in place purely by the mechanical pressure exerted by pins or knife-edged clamps. The metal-plated, wire-mounted method includes the resonant-wire mounts (not the resonant-pin mounts) and the metal-plated, edge-clamped, cemented-lead mount.

Moisture Resistance Test *(See paragraph 2-41)*

Nomenclature of Crystal Units

2-17. The Joint Army, Navy, Air Force nomenclature for designating a particular type of crystal unit is as follows:

CRYSTAL UNIT NOMENCLATURE

Item Name	*Type Number*		
Crystal Unit	CR	— XX	/ U
	Component Indicator	Number	Equipment Indicator Letter for Type of Installation

In the type number, the component, which is a crystal mounted in a holder, is identified by the symbol, CR. The component symbol is followed by a hyphen and 2 digits (-XX) which identify the mounted crystal as having been designed according to certain specified electrical and physical characteristics. The letter U, separated from the number by a slant sign, is the equipment indicator symbol for "general utility installation," which means that the crystal unit is intended for use in two or more of the three general installation classes—airborne, shipboard, and ground.

Nominal Frequency Tolerance

2-18. The maximum permissible difference between the rated nominal frequency of the crystal unit and the operating frequency as measured according to the specified test conditions. The tolerance is normally expressed as a given percentage of the nominal frequency and is applicable over the entire operating range unless the crystal unit is intended for oven mounting. In this latter case, the nominal frequency tolerance usually applies only to operation at the midpoint of the operating temperature range. An additional permissible deviation from the measured midpoint frequency is then specified, so that the overall frequency tolerance is equal to the sum of the nominal frequency tolerance and the additional permissible frequency deviation.

Operable Temperature Range

2-19. Temperature range over which the crystal unit has been tested in operation without regard to tolerance limits. Normally, the operable temperature range is specified only for crystal units having a narrow operating temperature range—that is, only for those units standardized for use in temperature-controlled compartments. The specification of an operable temperature range provides assurance of the continued operation of a crystal, although not necessarily within the frequency tolerance limits, during an oven warm-up period, or during the breakdown or absence of temperature control. However, it should be understood that the term "operable" is not rigorously defined. A crystal unit operable in the average test circuit may not be operable in an oscillator that is designed for minimum performance characteristics when the effective resistance is the maximum permissible value.

Operating Temperature Range

2-20. That part of the operable temperature range within which the crystal unit tolerance specifications have been tested and are assumed to hold. Unless the crystal unit is intended to be temperature-controlled, the operating and the operable ranges are identical.

Ordering Requirements *(See paragraph 2-49)*

Packaging Requirements *(See paragraph 2-50)*

Pin Alinement Test *(See paragraph 2-42)*

Plating Adherence Test *(See paragraph 2-43)*

Reference Standard Test Set *(See paragraph 2-58)*

Requirements and Procedures of Tests

2-21. See Military Specification MIL-C-3098( ) for details of the required inspections, the grouping of tests, and the procedure for sampling. Those tests performed on each individual crystal unit by the manufacturer are the visual and mechanical external inspection, the frequency and effective resistance test, the second level of drive test (for overtone units), and the seal test. Samples of each production lot are subjected to all remaining tests listed herein which are specified as applicable.

FABRICATION REQUIREMENTS

Bonding

2-22. Wire-mounted, metal-plated crystal units are bonded at the point of contact of the suspension wire and the metal plating of the quartz plate. A conductive material of the highest grade commercially available and suitable for the purpose is used. The bond withstands, without electrical or mechanical failure, all tests performed on the crystal unit.

Crystal Holders

2-23. All holders conform to Military Specification MIL-H-10056( ).

Electrical Connections

2-24. When the design of a crystal unit involves the use of a nonferrous metal in direct contact with the metal plating, a tin-lead eutectic solder saturated with the same metal used for plating the quartz surfaces is employed. Saturation of the solder with the plating metal is such that during soldering, or thereafter, migration of the metal from the plated surface of the quartz plate to the solder is effectively checked. Springs are attached to the base pins by using a high-temperature solder or by welding.

Etching

2-25. The quartz plates are finished by etching to the final frequency for pressure-mounted units and to the preplating frequency for metal-plated units. During manufacture, at least one freshly-lapped quartz plate of each type being processed is taken at random from the production line each day for measurement of its frequency under standard test conditions. The quartz plate is then subjected to the etch procedure being used by the manufacturer and tested for compliance with the etching specifications of the Military. AT and BT plates must be subjected to the following minimum etch for fundamental and overtone operations:

Fundamental		*Overtone*
$\Delta f = 0.6f^2$	(AT Cut)	$\Delta f = 0.3f^2/N$
$\Delta f = 0.4f^2$	(BT Cut)	$\Delta f = 0.2f^2/N$

Where:

Δf = required frequency increase in kc.
f = frequency of quartz plate in mc.
N = harmonic.

The above formulas are based upon the use of 1000-mesh grit abrasive. In the event a manufacturer uses a finer grit abrasive requiring an amount of etch less than that indicated above, he is required to demonstrate to a government inspector that the amount of etch is above the knee of the etch-rate curve, or is a satisfactory equivalent. (The etch-rate curve is the curve produced by plotting frequency change due to etching as the ordinate against time of etch as the abscissa. The knee of the curve is that portion of greatest curvature, which occurs at the beginning of the curve before the rate of frequency change has become a steady slope.) The etching curves (not etch-rate curves) in figure 1-89 are graphical illustrations of the fundamental-frequency formulas above.

Glass Seal (See paragraph 2-37)

Marking

2-26. The type number, the specified nominal frequency, and the code letters designating the manufacturer are permanently and legibly marked on the holder of each crystal unit. Unless otherwise specified by the bureau or service concerned, no other markings are permitted on the holder. The code designating letters are those listed in publication NAVSHIPS 900,152. Each line of characters is symmetrically located with respect to the center axis of the holder. Characters are not less than one-sixteenth inch high and are either metal-stamped, branded, or engraved. The marking is required to withstand all tests specified for the particular crystal unit.

Mounting

2-27. The quartz plate will be either wire- or pressure-mounted.

Solder

2-28. Soft solder is used in accordance with Federal Specification QQ-S-571, and is required to have a minimum tin content of 39.0 per cent by weight, except in the case of the electrical connections to the metal plating on the quartz as described in paragraph 2-24. In the edge-clamped wire mounts, the solder is not used primarily for obtaining mechanical strength, and the electrical connections are mechanically and electrically continuous before and after soldering.

Solder Flux

2-29. Only substantially noncorrosive fluxes are used unless the corrosive element can be demonstrably removed after soldering.

Workmanship

2-30. All crystal units are required to be manufactured and processed in a careful and workmanlike manner, in accordance with good commercial design and practice. All units are required to be free from any imperfections which may affect their serviceability, and the interiors must be free from flux, loose solder, unapproved or foreign material, dust, or any loose particles at all.

STANDARD TEST CONDITIONS

2-31. Unless otherwise specified, all crystal-unit measurements and tests are made under the prevailing ambient conditions of atmospheric pressure and relative humidity and at a temperature between 20 and 35 degrees centigrade. When measurements of the frequency and/or effective resistance are made both before and after a test, the temperature of the crystal unit for the second measurement is required to be within 2 degrees centigrade of the temperature of the first measurement, and the level of drive for all measurements is to be within 20 per cent of the nominal value specified.

DESCRIPTIONS AND REQUIREMENTS OF TESTS

Aging Test

2-32. The crystal unit is placed in a well-ventilated oven equipped with heating and timing controls that produce the following heat cycle: a "heat-on" period of 2 hours duration with a stabilized temperature of 100 degrees centigrade ($\pm 5°C$) for at least 30 minutes, followed by a "heat-off" period of sufficient duration to lower the oven to within 15 degrees centigrade of standard test conditions. The crystal unit is subjected to three such continuous cycles and then removed from the oven at the end of the final "heat-off" period, after which the frequency is measured for compliance with the tolerance specifications of the aging test. The specified maximum permissible change in frequency can be assumed to be an approximate gauge of the degree of frequency drift the crystal unit can be expected to undergo due to aging after being in operation a long period of time.

Corrosion Test

2-33. The crystal unit is required to withstand 50 hours of the salt-spray (fog) test specified in Federal Specification QQ-M-151 without evidence of corrosion sufficient to impair the operation of the crystal unit.

Drop or Shock Test

2-34. This test is imposed to prove out the mechanical design of the unit to meet normal handling and military environmental conditions. It provides sharp mechanical shock. Method 202 as specified in MIL-STD-202 is recommended for uniformity and duplication of test results. The test is also described as Method A of MIL-C-3098B. The frequency and effective resistance are measured before and after the test. The change in frequency is not to exceed the tolerance specified for the drop test, and the effective resistance is not to exceed the maximum specified for the crystal unit.

Effective Resistance Test at Second Level of Drive for Overtone Crystal Units

2-35. The effective resistance of overtone crystal units is checked at a second and lower level of drive at room temperature to ensure that the specified maximum effective resistance is not exceeded when the amplitude of crystal vibration approaches a practical minimum. The second level of drive is obtained by setting up Crystal Impedance Meter TS-683/TSM in accordance with the applicable instructions contained in Military Specification MIL-C-3098B.

Frequency and Effective Resistance Test Over Operating Temperature Range

2-36. The crystal unit is tested in accordance with method A or B, as specified. Unless otherwise specified, the level of drive during the test is within 20 per cent of the nominal drive level specified for each crystal unit. The reference standard test sets are as specified on the standard sheet in MIL-C-3098B. The drive adjustment procedures for the test set and particular crystal unit are also specified in MIL-C-3098B. The measured crystal frequency is to be within the tolerance specified, and the measured effective resistance is not to exceed the maximum specified.

a. Method A: The crystal unit is subjected to a temperature run over the specified operating temperature range at a minimum rate of change of 3 degrees centigrade per minute. Measurements of frequency and effective resistance are made at intervals no greater than 3 degrees centigrade, except that the portion from −30 to +20 degrees centigrade is completed in a period not exceeding 1 minute, and continuous readings of both frequency and effective resistance are made over the range. The entire temperature range of −55 to +90 degrees centigrade is not to be completed in less than 1 minute.

b. Method B: The crystal unit is subjected to a temperature run over the specified operating temperature range at any convenient rate of temperature change. Measurements of frequency and effective resistance are made at intervals no greater than 3 degrees centigrade.

Glass Seal Inspection

2-37. Those crystal units with bases having a glass seal are inspected with the aid of a strong light and 10-power magnification. No glass seal is permissible that contains radial or other detrimental cracks.

Immersion Test

2-38. The crystal unit is immersed in water, maintained at 90° to 95°C, for at least 1 hour. Unit is then removed from water, wiped dry, and set aside for one-half hour, after which its insulation resistance, frequency, and effective resistance are measured and compared with those made before the immersion test. Also, markings on the crystal unit must remain legible.

Insulation Resistance Test

2-39. At room temperature, using a test voltage of 50 to 100 volts, the insulation resistance of the crystal unit, as measured between the pins of the unit or between any pin and any other external metal part of the unit, is required to be not less than 500 megohms.

Internal Inspection

2-40. Randomly selected samples of crystal units from an inspection lot are disassembled and the interior of each selected unit is inspected to determine if the material, threaded parts of the holder, and the workmanship comply with military specifications.

Leakage

2-40a. After being held at standard test conditions for a period of at least 24 hours, the sealed crystal unit is immersed in an open container of distilled water. The container is then placed in a sealed chamber which is evacuated to an absolute pressure of 3.0 to 3.4 inches of mercury for a period of not less than 5 minutes. There must be no evidence of leakage of gas or air from inside the unit.

Moisture Resistance Test

2-41. The crystal unit is subjected to a series of thirty 24-hour moisture resistance tests in a humidity test chamber. For the first 16 hours of each test period, the chamber is maintained at 65° ± 2°C, and above 90% relative humidity. For the last 8 hours, the chamber is returned to normal room temperature. After 4 or more days, and for at least 6 times within the 30-day test period, and at the end, the unit is removed from the chamber and tested for effective resistance, frequency, and insulation resistance.

Pin Alinement Test

2-42. Crystal units having a type HC-6/U, HC-13/U, or HC-14/U holder are tested for correct pin alinement by using a shadowgraph as specified in Military Specification MIL-H-10056( ), or by using a test gage as specified in Military Specification MIL-C-3098( ). The test gage is equivalent to a 2-hole socket having a depth of 0.238 ± 0.01 inch. The two holes are spaced 0.486 inch center-to-center, and each has a maximum diameter of 0.06 inch. Pins so tested must freely enter the gage until the base of the holder is firmly seated on the gage.

Plating Adherence Test

2-43. The plating adherence test is applicable to all crystal units employing metal-plated crystals. The test is performed by firmly applying a piece of transparent plastic pressure-sensitive tape to the base plating of the quartz crystal, and then removing the tape immediately by lifting one corner and pulling at a slow uniform rate perpendicularly to the plated surface. The above steps are repeated for units that have been plated to the final frequency. After the test there must be no visual evidence (without magnification) of the removal of plating from the quartz surface.

Seal Test

2-44. After being held at standard test conditions for a period of at least 24 hours, the sealed crystal unit is immersed in water having a temperature between 90°C and 95°C for a period of not less than 2 minutes. A seal is considered defective if an escapement of bubbles from the holder is observed, indicating a gas or air leakage from the inside of the crystal unit.

Spurious Frequency Test

2-45. With the reference test set adjusted to provide the specified drive level at standard test conditions, a fixed resistor, whose value is equal to the specified maximum effective series resistance, is substituted for the crystal unit. The output frequency of the test set is then adjusted to both plus and minus 10 per cent of the nominal frequency marked on the crystal unit, and the respective dial settings of the tuning control on the test set are recorded. With the fixed resistor replaced by the crystal unit, the tuning control is varied slowly between the recorded dial settings. The crystal unit is assumed free of spurious responses if during this tuning variation neither abrupt shifts in frequency nor intermittent oscillations are observed.

Tensile Strength Test

2-46. This is a test of the mechanical strength of the junction of the metal plating and lead wires. This test is generally applied in the case of the lower-frequency wire-mounted units where it is usual for the entire mechanical support of the crystal to depend upon the soldered junctions of the lead wires to the metal plating of the crystal. When the test is applicable, the minimum permissible tensile strength of the junction is specified for each particular type of crystal unit and frequency band. A weight load is gradually applied to the outside ends of both of the lead wires until breakdown occurs at the junction to the metal plating. (Breaking of the quartz plate during the test is not construed as a test failure and another specimen is taken.) A breakdown must not occur at a tensile pull less than that of the minimum weight specified.

Terminal Polarity Test

2-47. The crystal unit is operated in a test set in which the socket is non-polarized, and the frequency, as measured under standard test conditions, must be as specified.

Vibration Test

2-48. Each type of Military Standard crystal unit must undergo the same rigorous test in a vibration machine. The maximum changes in frequency and effective resistance resulting from the test period of vibration that are permissible are specified for each particular type of crystal unit. The crystal unit is rigidly mounted with random orientation on the platform of a vibration machine. A simple harmonic motion having a peak amplitude of 0.015 inch (maximum total excursion of 0.030 inch) is applied to the platform continously for 2 hours. The frequency of the applied vibration is varied uniformly between the approximate limits of 10 and 55 cycles per second. The entire frequency range from 10 to 55 cps and return is traversed in 1 to 2 minutes. The frequency and effective resistance are measured under standard test conditions before and after the test, and the changes observed in these parameters are not to exceed the tolerances specified.

DELIVERY REQUIREMENTS

Ordering

2-49. According to Military Specification MIL-C-

3098B, procurement documents should specify the following:

a. Title, number, and date of the applicable crystal unit specification (MIL-C-3098B).

b. Type designation (type number), and the title, number and date of the applicable Military Standard. (Crystal units designated as "special application" shall be purchased and used only with the approval of the bureau or service concerned.)

c. Nominal frequency required.

d. Laboratory where preproduction tests are to be conducted. (See MIL-C-3098( ) for requirements of preproduction tests.)

e. Whether crystal units are to be packaged individually or in sets.

f. Whether metal boxes or fiberboard cartons or boxes are to be used for set packaging.

g. Whether intermediate packages are required, and quantity of individual packages.

h. Whether packing and marking are for domestic or oversea shipment.

i. That the contractor shall not substitute for a specified material or fabricated part unless he obtains approval for such substitution from the bureau or service concerned. Evidence to substantiate his claim that such a substitute is suitable shall be submitted with his request. Similar notification and substantiating evidence shall be submitted at any later time if substitution becomes necessary or desirable. At the discretion of the bureau or service concerned, test samples may be required to prove the suitability of the proposed substitute.

j. Applicable reference standard test set to be furnished by the contracting officer to government inspector at the manufacturer's plant.

Packaging

2-50. When directly purchased by or directly shipped to the Government, Military Standard crystal units must either be packed individually or in sets composed of one crystal unit of each designated frequency. When packed individually, each unit is cushioned and packaged in a folded carton or set-up box conforming to Specification JAN-P-120 or JAN-P-133, respectively. When packaged in sets, each set is contained in a hinged-cover-and-clasp-style enameled or lacquered metal box satisfactory to the bureau or service concerned, or in fiberboard boxes, set-up boxes, or cartons, as specified, with each crystal unit individually wrapped or cushioned. The quantity included in a unit package is 10 or a multiple thereof. Five unit packages or a multiple thereof are further packaged in intermediate containers conforming to Specification JAN-P-120 or JAN-P-133. The gross weight of the intermediate container is not to exceed 5 pounds. See MIL-C-3098B, Section 5, for detailed packaging and marking instructions. However, it should be understood that the military specifications concerning the packaging, packing, and marking of crystal-unit shipments to the Government are not intended to apply to contracts or orders between the manufacturer and prime contractor.

Resonance *(See paragraph 2-57)*

Seal Test *(See paragraph 2-44)*

Second Test Level of Drive

2-51. A very low level of crystal drive used for checking the effective series resistance of overtone crystal units at minimum amplitudes of vibration. This second check is necessary because of the tendency among overtone units to exhibit sharp increases in effective resistance as the crystal drive approaches zero. The procedure for obtaining the second level of drive, which is applicable to the use of Crystal Impedance Meter TS-683/TSM, is specified in Military Specification MIL-C-3098B.

Solder Requirements *(See paragraph 2-28)*

Solder Flux Requirements *(See paragraph 2-29)*

Special Application Crystal Units

2-52. Crystal units assigned a status of "special application" are available only in limited production and normally from only one source (availability category 2). Such crystal units are not to be purchased and used without the approval of the service or bureau concerned.

Spurious Frequency Test *(See paragraph 2-45)*

Standard Crystal Units

2-53. Crystal units assigned a status of "standard" are available from two or more sources (availability category 1) and are recommended for use when applicable without special approval of the service or bureau concerned.

Standard Test Conditions *(See paragraph 2-31)*

Status

2-54. Type classification of crystal unit, regarding procurement and availability, as assigned by the cognizant Military agency.

Tensile Strength Test *(See paragraph 2-46)*

Terminal Polarity Test *(See paragraph 2-47)*

Test Level of Drive

2-55. The power, within ±20 per cent, usually expressed in milliwatts, that is to be supplied to the crystal unit when the unit is being tested with the specified reference standard test set for frequency and effective resistance. The test level of drive is also the maximum drive at which the crystal unit can be operated with assurance that the rated tolerances will be met, although the crystal is usually operable at much higher, but nonrecommended levels.

Test Load Capacitance

2-56. Capacitance with which the effective inductance of the crystal unit is resonant during the frequency and effective-resistance test. (Applicable only if the crystal-unit specifications call for parallel-resonance testing.) The circuit in which a parallel-mode crystal unit is intended to operate should be designed and adjusted to provide the unit with a load capacitance equal to the test load capacitance, otherwise no guarantee exists that the specified tolerances in frequency and effective resistance can be met. Since a given effective reactance of a crystal unit will occur at a unique frequency, a circuit can be assumed to be adjusted to present the correct load capacitance if the frequency is exactly the same as that measured when the crystal unit is known to be series-resonant with its test load capacitance under standard test conditions.

Test Resonance

2-57. States whether crystal unit is tested for operation at its resonance frequency (series-mode operation) or at some slightly higher frequency appropriate for parallel-mode operation.

Test Set (Reference Standard Crystal Impedance Meter)

2-58. Reference standard CI meter specified for use in measuring the frequency and effective resistance of the crystal unit.

USAF Stock No.

2-59. Number for identifying item when requisitioning from U. S. Air Force supply depot. The USAF stock numbers of crystal units are the same as the respective Signal Corps numbers except that the prefix "2100-" is added, which serves to identify the item as belonging to USAF stock class 16-F. The exact frequency is identified by a hyphen-separated suffix equal numerically to the frequency desired in kc.

Vibration Test *(See paragraph 2-48)*

Workmanship Requirements *(See paragraph 2-30)*

MILITARY STANDARD DRIVE ADJUSTMENT PROCEDURES FOR CRYSTAL UNITS COVERED BY MILITARY SPECIFICATION MIL-C-3098B

Crystal Impedance Meter TS-330/TSM

PROCEDURE FOR OBTAINING TEST LEVEL OF DRIVE FOR CRYSTAL UNITS OVER A FREQUENCY RANGE OF 800 TO 15,000 KILOCYCLES PER SECOND

2-60. The following drive adjustment procedure is specified by Military Specification MIL-C-3098B, Paragraph 4.3.1.1.1:

a. Set band switch of TS-330/TSM test set to the appropriate frequency.

b. Set "crystal-calibrate" switch to "calibrate" position.

c. Determine, from the table below, the value of resistance for the frequency range of the type of crystal unit being tested. Set this value of resistance on the decade resistor in the test set.

d. Select, from the table below, the value of test frequency shown for the frequency range of the type of crystal unit being tested. Adjust the test set to this frequency by means of the tuning control. (Great precision is not essential in this frequency setting. The adjustment may be accomplished by monitoring the test-set signal by means of a calibrated radio receiver with dial settings comparable in accuracy to that of the National high-frequency receiver type HRO-SP.)

e. Determine, from the table below, the value

Frequency Range (mc)	*Test Frequency (mc)*	*Non-Temperature-Controlled Units*		*Oven-Controlled Types*	
		Resistance (ohms)	*Crystal Current (ma)*	*Resistance (ohms)*	*Crystal Current (ma)*
0.80— 1.50	1.3	100	10	0	0**
1.51— 2.25	2.0	50	20	90	10
2.26— 3.40	3.0	100	10	50	10
3.41— 5.10	*	45	15	50	10
5.11— 7.50	*	25	20	22	15
7.51—10.00	*	16	25	13	20
10.1 —15.0	*	13	20	11	15

* Set up at frequency of crystal to be tested.
** Set for minimum setting of "crystal current" control.

of crystal current for the frequency range of the type of crystal unit being tested. Vary the crystal current control on the test set until the crystal current meter indicates the proper value.

f. The drive in the test set is now properly adjusted for crystal units of the frequency being tested and for crystal units in the frequency range for which the adjustment was made.

Crystal Impedance Meter TS-537/TSM

PROCEDURE FOR OBTAINING TEST LEVEL OF DRIVE FOR CRYSTAL UNITS OVER A FREQUENCY RANGE OF 75 TO 1100 KILOCYCLES PER SECOND

2-61. The following drive adjustment procedure is specified by Military Specification MIL-C-3098B, Paragraph 4.3.1.1.2:

a. With the crystal drive control set for the minimum value at which the crystal will oscillate, measure the effective resistance of the crystal as described in the TS-537/TSM instruction manual.

b. Determine the voltage across the measured value of effective resistance that would provide a 2-milliwatt power dissipation. Use graph in MS-91482, or the following formula:

$$\text{Volts} = \sqrt{0.002 \text{ x Effective Resistance in Ohms}}$$

c. With the test set in the "calibrate" position, and with the decade resistor set for the effective resistance determined in step a, adjust the crystal drive control until the voltage difference obtained in step b appears across the decade resistance. This voltage difference can be measured by obtaining the difference between two vacuum-tube voltmeter readings taken at the voltmeter jacks on the front of the test set. If the drive cannot be decreased sufficiently, set the crystal drive control for minimum drive.

Crystal Impedance Meter TS-683/TSM

PROCEDURE FOR OBTAINING TEST LEVEL OF DRIVE FOR CRYSTAL UNITS OVER A FREQUENCY RANGE OF 10,000 TO 100,000 KILOCYCLES PER SECOND (10.0 TO 100.0 MEGACYCLES)

2-62. The following drive adjustment procedure is specified by Military Specification MIL-C-3098B, Paragraph 4.3.1.1.3.1:

a. Set band switch of the TS-683/TSM test set to the appropriate frequency.

b. Adjust frequency of the test set to the frequency of the crystal unit by means of the calibrated dial.

c. Determine, from the table below, the value of resistance for the frequency range of the type of crystal unit being tested. Obtain a non-wire-wound type resistor that does not differ from the selected value by more than 2 per cent. (The resistor, for convenience, may be mounted in a type HC-6/U crystal holder.)

d. Insert the resistor in the appropriate socket. It is necessary to fabricate a jig, in which to place the resistor, that will permit the measurement of voltage from both sides of the resistor to ground. This measurement shall be made with a high-frequency probe of the type used in a Model 1800-A General Radio vacuum-tube voltmeter, or equal.

e. Determine, from the table below, the value of resistor voltage drop for the frequency range of the type of crystal unit being tested.

f. By means of the voltmeter specified in step d, measure the voltage from both sides of the resistor to ground and subtract the smaller reading from the larger to determine the resistor voltage drop.

g. Vary the drive control at the rear of the test set and repeat the voltage measurements until the measured resistor voltage drop is equal to that specified in the table.

h. The drive in the test set is now properly adjusted for crystal units of the frequency being tested and for crystal units in the frequency range for which the adjustment was made.

Frequency Range (mc)	*Resistance (ohms)*	*Resistor Voltage Drop (volts)*	
		Non-Temperature-Controlled Units	*Temperature-Controlled Units*
10—24.99999	40	0.40	0.28
25—52.0	40	.28	.20
52.000001—75	60	.35	.24

NOTE: The resistance and voltage values in the table above are not applicable in the case of the 20-milliwatt crystal units, CR-51/U and CR-53/U. See the respective technical descriptions of these crystal units for the parameters providing the correct test level of drive.

PROCEDURE FOR OBTAINING TEST LEVEL OF DRIVE FOR CRYSTAL UNIT CR-33/U

2-63. The following drive adjustment procedure is specified by Military Specification MIL-C-3098B, paragraph 4.3.1.1.3.2:

a. Insert a ⅛- or ¼-watt carbon resistor having a value of 25 ± 1 ohms, measured on a wheatstone bridge, in the appropriate socket. (The resistor can be mounted on the base of a type HC-6/U crystal holder, with the resistor leads soldered to the mounting pins and kept as short as possible.)

b. Adjust frequency of the test set to the frequency of the crystal unit by means of the calibrated dial.

c. Adjust the screen-grid control knob to present a value of 0.25-volt difference between the voltages when measured from each side of the resistor to ground. This sets up the required level of drive of 2.5 milliwatts.

d. Remove the 25-ohm resistor and insert another carbon resistor having a resistance equal to the maximum effective resistance specified for the crystal unit on Military Standard MS91388.

e. Retune the test set as in step b above.

f. Adjust the knob marked "grid current increase" to read some convenient value of grid current on the microammeter. This value of grid current may then be used to represent the maximum effective resistance. The test set is now adjusted for "Go and No-Go" operation.

g. Remove the resistor and insert the crystal unit with its 32 ± 0.5 microfarad load capacitance in series with one terminal. The test set may now be used to perform the frequency and effective resistance measurements of the crystal unit.

PROCEDURE FOR OBTAINING SECOND TEST LEVEL OF DRIVE FOR HARMONIC-MODE CRYSTAL UNITS UTILIZING CRYSTAL IMPEDANCE METER TS-683/TSM

2-64. The following drive adjustment procedure is specified by Military Standard MS90168 (19 November 1952 revision):

a. With the appropriate calibrating resistor for the frequency involved, the screen voltage control shall be set to a point at which the rectified grid current reading is one-half of one meter division (2.5 μa) greater than the non-oscillating reading. This shall be checked by alternately inserting and removing the resistor and observing the meter deflections. Greatest accuracy will be obtained when operating the grid meter shunt control at maximum clockwise position.

b. The tuning control of Crystal Impedance Meter TS-683/TSM shall be adjusted in the usual manner for proper frequency calibration, using the appropriate resistor.

c. The crystal unit shall be inserted in the socket of the test set, and the grid current meter shall show a deflection increase of at least one-half of one meter division (2.5 μa). Crystals that do not oscillate or produce readings of less than one-half of one meter division (2.5 μa) shall be considered defective. The crystal oscillation frequency can be monitored in the receiver used in calibrating, as an aid to increasing the speed of testing.

Crystal Impedance Meter TS-710/TSM

PROCEDURE FOR OBTAINING TEST LEVEL OF DRIVE FOR CRYSTAL UNITS OVER FREQUENCY RANGE OF 10 TO 1100 KCS

2-65. The following drive adjustment procedure is specified by Military Specification MIL-C-3098B, paragraph 4.3.1.1.4:

a. Determine the proper power level from the applicable military standard.

b. Compute the required value of substitution resistance by taking 70 percent of the maximum (crystal unit) resistance given on the applicable military standard for the crystal unit under test.

c. Using the data obtained under steps a and b above, determine the crystal unit drive voltage from the formula $E = \sqrt{WR}$

Where

E = drive voltage in volts.
W = specified power level in watts.
R = resistance in ohms found in step b.

d. Insert the correct value of substitution resistance, as obtained in step b above, in the crystal-unit socket; switch the oscillator circuit to series-resonance operation; tune the test set to the frequency of the crystal unit under test; adjust the voltage gain control to obtain the voltage difference required by step c. This voltage difference may also be obtained by measuring the voltage between each terminal of the crystal-unit socket to ground, with the substitution resistor in the socket, and computing the numerical difference.

METHODS FOR MEASURING THE FREQUENCY OF MILITARY STANDARD CRYSTAL UNITS

2-66. The systems employed by manufacturers and laboratories for measuring the frequencies of crystal units vary according to the facilities available, the degree of precision desired, the temperature requirements, the purpose of the particular measurement, and other factors. For example, in a simple room-temperature test of the go, no-go* type, a less elaborate system is required than would be the case if a very precise record of the frequency were desired over an operating temperature range of —55° to 75° C. Again, the measuring systems employed in testing crystal units at points along a production line are arranged to permit simple, repetitive operating techniques that can be readily learned by non-technical personnel. In the research laboratory, on the other hand, the test equipment must be adaptable for a wide variety of measurements over wide frequency ranges and ambient test conditions. Since such tests are to be performed by highly trained technicians, less attention is given to simplified techniques. Normally, the equipment available can be used in a number of different ways to obtain the same measurement, some of the methods being more accurate than the others.

EQUIPMENTS REQUIRED FOR CRYSTAL FREQUENCY TESTS

2-67. In the measurement of crystal frequencies under test conditions corresponding to Military Specifications, the equipments required can be divided into the following categories:

Primary Standards

a. Primary frequency standard (Station WWV ground-wave signals)

b. Primary crystal test set standards (Government-furnished CI meters to be used for correlation adjustments) †

c. Primary load-capacitor standard

d. Primary calibrated resistor standards

e. Primary temperature standards (boiling and freezing points of water)

Reference Standards

a. Secondary frequency standard (precision crystal-controlled frequency generator)

b. Audio-frequency reference standard (interpolation oscillator)

c. Reference crystal test sets (standard CI meters and duplicating circuits used in actual crystal-frequency measurements)

d. Temperature reference standard (pyrometer)

e. Reference load capacitors (component parts of reference crystal test sets)

f. Reference calibrated resistors

Indicating and Recording Instruments

a. Frequency counter or meter

b. Frequency-deviation meter

c. Frequency-deviation-vs-temperature recorder

d. Oscilloscope (used in exact frequency measurements and in correlation of interpolation oscillator)

e. Grid-current meter (used in adjustment of reference crystal test set for measuring crystal resistance)

f. Effective-resistance-vs-temperature recorder

g. Electronic r-f voltmeter (used in measuring crystal drive level)

h. Pyrometer (for indicating crystal temperature—same as temperature reference standard, listed above, used in correlating other temperature-measurement controls)

i. Thermometer (for cold box or multiple-crystal cooling and heating chamber)

j. Q meter (for calibration of load capacitance)

k. R-F bridge (for checking calibrated resistors)

l. Earphones or loudspeaker (for audio zero-beat frequency measurements)

Auxiliary Amplifiers and Frequency Converters

a. Radio receiver, cw and mcw

b. Harmonic generators (controlled by frequency standard)

c. Frequency divider (for dividing frequencies that are too high for receiver)

d. Variable-frequency oscillator (for rapid frequency checks)

e. R-f amplifier

f. D-c amplifier

* "Go, no-go" is a technical idiom for the type of test in which a component is tested only for acceptance or rejection; that is, an exact measurement is not necessary. The test need only be sufficient to determine whether or not the specified tolerances are exceeded.

† Government-furnished C. I. meters are not correctly primary standards; officially, they are called "Government Reference Standard Test Sets." See paragraph 2-72 for explanation of terms, "primary standard" and "reference standard" as used in this text.

g. Signal control panel

Auxiliary Devices for Controlling Crystal Unit Test Conditions

a. Cold box

b. Cold box thermostat

c. Heater

d. Heater thermostat

e. Variable heater power source (a-c, 0-125-V, 5-watt Powerstat typical)

f. Timer (for correlation of heater power supply with proper rate of temperature change)

g. Dummy crystal units (for mounting thermistor or thermocouple temperature sensing element of pyrometer)

h. Transparent adhesive tape (for binding together dummy crystal units)

i. Thermocouple wire, AWG #26 or smaller

j. Vibration machine

k. Crystal mounting fixture for vibration machine

l. Shock testing machine

m. Container for immersion test

n. Ten-power microscope

o. Micrometer

p. Pin-alignment gauges and/or shadowgraph

q. Socket adapter for Crystal Holder HC-10/U (Crystal Socket Adapter UG-683/U, available from Walter L. Schott Co.)

Test-Plant Fixtures

a. Primary power source (110 volts, ac)

b. Secondary regulated power source, if advisable

c. Mounting facilities (cabinets, shelves, benches, tables, stands, frames, racks, etc)

d. Cabinet facilities for storing records and expendable supplies

e. Desk facilities

f. Vibration-free area of building

g. Thermostatically controlled room

2-68. Brief functional descriptions of the equipments listed above are given below wherever the exact use of a unit is not self-evident. The descriptions follow the same order as in the outline above. The model mentioned to illustrate each type of equipment is to be interpreted as representative only. Equivalent, and probably improved, models for most of the types of equipment listed are generally available from the same manufacturer as well as from other manufacturers. The examples given as representative are the equipments currently being used by, or in developmental projects under the technical control of, the Frequency Control Group of the Communications and Navigation Laboratory, Wright Air Development Center.

Primary Standards

2-69. Every arithmetical measurement involves the division of the quantity being measured into countable units. Where the object of the measurement is to make a relatively precise determination of the total number of units contained in the given quantity, it is necessary that *the quantity and the test conditions,* as well as *the measuring unit,* be well defined. For example, if the quantity being measured is the length of an iron bar, a precise measurement requires that the temperature of the bar be specified; otherwise, the particular length being measured, which would be different for each temperature, would not be known. Consequently, a measurement of the length also involves a measurement of the temperature, which, in turn, requires that the unit of temperature also be well defined. In general, the more precise the major measurement, the larger the number of auxiliary minor measurements to be made in order to establish the required test conditions. For each contemplated measurement, major or minor, a standard must be available to ensure the accuracy of the measured units. The accuracy of the measurement, of course, cannot be greater than the accuracy of the standard.

2-70. Before a numerical measurement can be made, a unit of measurement must be decided upon. Most, if not all, types of basic physical quantities now have internationally accepted units. These units, defined as concretely as practicable, are called *absolute units.* Measuring devices, constructed with the greatest possible precision to represent the absolute units, are stored in the chambers of the International Bureau of Weights and Measures in Sèvres, France. These physical objects by common agreement serve as *international standards.* The units which the standards define are called *international units.* Theoretically, the international units are supposed to equal the absolute units, and so they do to the nearest degree attainable at the time the standards are constructed. But improved methods of measurement which permit greater precision are constantly being developed, so it is not unusual for discrepancies to be found between the international and the absolute units. In time, more precise instruments are accepted as international standards in place of the old, but the interval of delay is usually quite extensive. As a result, where measurements of optimum precision are being made, knowledge of the exact degree of accuracy obtained is often obscured due to ambiguity regarding the accuracy of the reference units used as standards. Aiding the chance for ambiguity is the fact that each country has its own primary standards for domestic uniformity which may or may not be correlated with the international standards.

2-71. In the United States the national standards are controlled by the National Bureau of Standards, Washington, D. C. The official units of the United States are based on the yard-avoirdupois pound-second system of weights and measures rather than the meter-kilogram-second international system, but are, nevertheless, defined absolutely in terms of the international units. For example, the United States absolute yard is defined as equal to 3600/3937th of the international meter. Presumably the physical primary standard for length at the Bureau of Standards is one that has been carefully correlated with the International Prototype Meter at Sèvres. (The International Prototype Meter is the distance at 0° centigrade between two fine transverse lines engraved on a platinim-irridium bar. This international primary standard was originally intended to represent an absolute unit of one ten-millionth of the distance between the north pole along a meridian to the equator. The absolute meter now is defined to equal 1,533,164.13 wavelengths in air at 760 mm pressure and 15° centigrade of the red line exhibited by cadmium (vapor) during electrical discharge.)

2-72. Within the United States, the *primary standard* for a particular unit is officially the standard maintained by the National Bureau of Standards. Other official measuring devices are called *secondary standards* since they must be correlated with the national primary standards. For some units there have been established hierarchies of standards. Each office has its own standard, which is checked against a local standard, which, in turn, is checked against a regional standard, and so on up to the national primary standard. Such is the system used in meteorological stations in respect to a sequence of correlated barometers of ascending accuracy. A similar system of standards is not readily available for all the types of measurements normally required in the testing of crystal units. The standards available are a mixture of various orders of accuracy and officialty. In the list of equipments in paragraph 2-67 we have *arbitrarily* classified as *primary standards* those standards of maximum accuracy that are not used in the actual crystal tests, but are employed only by calibrating, adjusting, or in some way correlating the instruments that are being used as reference standards in making the actual measurements. These latter instruments, whether or not they are periodically checked against another standard, we designate as *reference standards.*

PRIMARY FREQUENCY STANDARD

2-73. To determine the frequency of any periodic event we must measure the number of times the event occurs during a given unit of time, or reciprocally, measure the number of time units contained in the duration of a given number of events. By either method the accuracy of the measurement will depend upon how accurately the unit of time is known. Unfortunately, we cannot freeze an interval of time and preserve it as a standard, so instead we rely upon the conservation of momentum to provide our standard. This is possible since a rotating body, if not acted upon by net external tangential forces, will turn through equal angles in equal intervals of time. The rotating earth is the internationally accepted time standard, there being no specially constructed standard as for the other fundamental units. The international unit, which is also the U. S. standard unit, is the *second*, which is defined to be 1/86400th of a mean solar day. A solar day is the noon-to-noon time between succeeding instances in which the center of the sun crosses the meridian of a fixed earth observer, as distinguished from a sidereal, or star, day. The former is the period of the earth's rotation on its own axis relative to the sun, whereas the latter, a slightly shorter time interval, is the period of the earth's rotation relative to the celestial universe. The sidereal day is essentially the same interval of time throughout the year, but the solar day fluctuates constantly and must be averaged over a long period. Actually, the earth is slowing down perceptibly due to the frictional losses of energy resulting from the tides; but its motions are now so well known and predictable that solar time can be estimated to accuracies on the order of one part in 10^8.

2-74. In the measurement of time, for each transit of the earth through a mean solar angle of one second, one standard cycle occurs; so that one complete rotation of the earth can be viewed as a sequence of 86400 standard cycles. Now, a radio signal is also a sequence of cycles. Should we call a given sequence a "frequency standard," instead of a "time standard", let it be clear that in changing the name we in no way change the nature of the phenomenon that the name symbolizes. If a radio signal can properly be described as a "frequency", so also might we describe a sequence of inch marks. If our unit of space-length is the yard, we can describe the *length* of the inch by comparison with the length of the yard by saying that the "frequency" is 36 inches per yard. But note that the number 36 is simply a ratio between two lengths. Where the sequence of marks is something absolute in matter, their frequency is a mental comparison in an observer's mind. Similarly, it can be said that a sequence of radio cycles has an inherent material reality, but that the cycle frequency is only an observed relation of the duration of a cycle compared with that of a standard cycle. Thus, a signal of 100 kc per second means that, if compared with the period of one standard cycle, the period of one radio cycle is one hundred thousandth part. If this signal is defined as a frequency standard, it means that the period of its individual cycles are to be considered standard secondary subunits of the second, in much the same sense that standard inch marks are considered subunits of the yard. For it is as a standard unit of time that a frequency standard is used in the measurement of unknown frequencies. The measurements are made by comparing the periods of unknown duration with the periods of standard duration, and then interpreting the measurements in terms of frequency.

2-75. A standard frequency cannot be assumed to have an *absolute value* of greater precision than either of the two unit cycles of which it is a ratio. That is, the accuracy of the absolute value cannot exceed the stability of the frequency-control device nor the accuracy of the fundamental unit of time. Some oscillators have a short term stability so perfect that over short periods of time unknown frequencies can be measured relative to the frequency standard with much greater precision than the absolute frequencies can be known relative to the international unit of time. If such oscillators could maintain their stability without slow drifts with aging, they could conceivably replace the solar standard in establishing an international prototype unit of time. At the present time such oscillators are not available, but the great stability of atomic and molecular frequencies and the recent developments in the methods of exciting and detecting them, such as the experiments with ammonium clocks at NBS, suggest that eventually perhaps an atomic international time standard will replace the solar standard.*

2-76. The national primary frequency standard is a battery of 100-kc crystal oscillators controlled by G elements at the National Bureau of Standards. Use of this standard is readily available to anyone living in the region immediately surrounding Washington, D. C., since the output of the standard is used to control the sequence of standard signals continuously broadcast from station WWV. The WWV standard signals (see figure 2-87) are at radio frequencies of 2,500 kc, 5,000 kc, 10,000 kc, 15,000 kc, 20,000 kc, and 25,000 kc and are available by tuning a receiver to any one of these channels. At regular intervals, whose duration serves as a national time standard, the WWV signals are modulated by standard audio frequencies of 440 cps and 600 cps, which can be used in calibrating an interpolation oscillator. For the calibration of r-f standards only the 30-second c-w intervals are employed.

2-77. The national primary standard can be assumed to have a relative stability on the order of 1 part in 10^9 over any 24-hour period, but the absolute frequency, the number of cycles per international unit of time, cannot be guaranteed beyond an accuracy of 1 part in 10^8. An additional restriction is that this accuracy is only possible if the standard signal is being received as a ground wave. If a sky wave is being received the constantly varying pathlengths due to movements of the ionosphere create doppler effects, so that the received signal is randomly frequency modulated.† Eventually, it is to be hoped that a chain of relay stations can make available WWV ground signals in all parts of the country. At the present time, one slave station, WWVH, is maintained in the Territory of Hawaii. If top precision frequency measurements are to be made in localities remote from both WWV and WWVH, the engineer should have available a high-stability secondary standard which can be periodically brought to Washington and checked against the official primary standard. For the calibration of standards having short-term instabilities greater than 2 or 3 parts per 10^8, the WWV and WWVH sky

* The most recent definition of the second that has been approved by the International Astronomical Union is contained in the *Excerpts from Meeting of International Astronomical Union, Dublin, Ireland, August 29 to September 5, 1955*. We quote: "The General Assembly of the I. A. U. approves the definition of the second proposed by the Comite International des Poids et Mesures, as follows: The second is the fraction of 1/315,569,259,474 of the length of the tropical year for 1900." Additional information is contained in the *National Bureau of Standards Report No. 1848* under the title, "Spectral Lines as Frequency Standards."

† If special equipment is available for counting the sky-wave cycles over relatively long intervals of time--1-second intervals, for example—the random frequency variations tend to average out, so that the percentile error introduced by ionospheric deviations can be made relatively negligible. A number of systems for accomplishing this are possible. Essentially the problem is to compare WWV seconds pulses with similar pulses derived from the local secondary standard, adjusting the frequency of the latter until an equality is established. For one solution to the problem see paragraph 2-92.

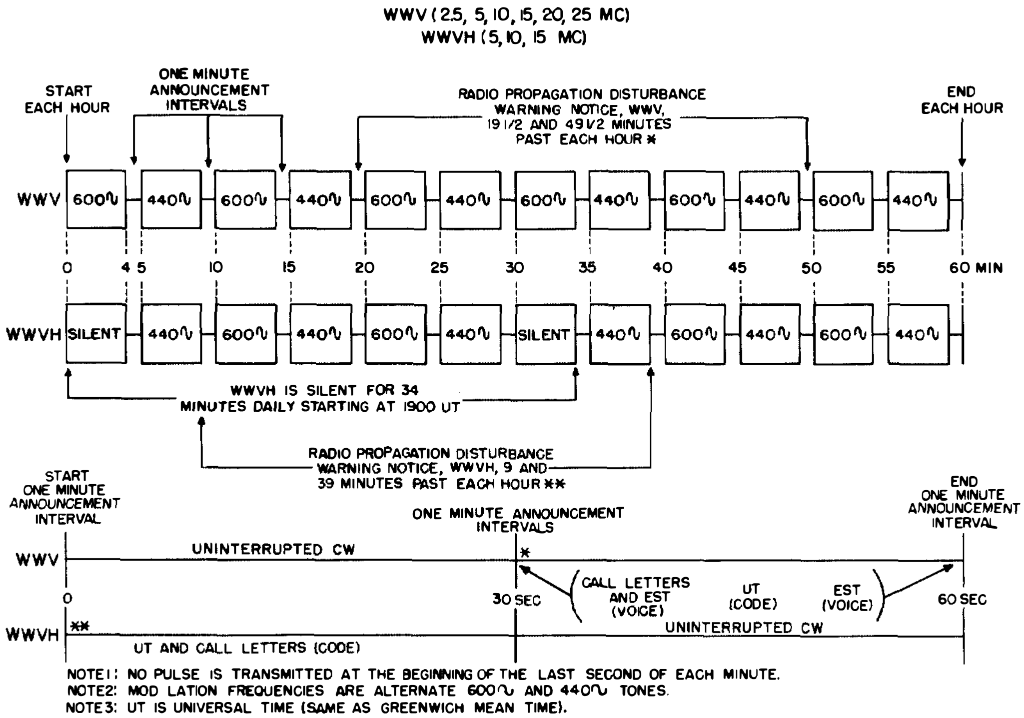


Figure 2-87. Chart showing standard time and frequency signals broadcast by Stations WWV and WWVH (Subject to change)

waves are satisfactory. These can be received on one channel or the other throughout the U. S.

PRIMARY CRYSTAL TEST SET STANDARDS

2-78. The specifications of Military Standard crystal units require that they be tested in standard reference sets. The primary standard test sets are Government-maintained models of the following types of crystal impedance meters:

Crystal Impedance Meter	*Frequency Range (kc/sec)*
TS-710/TSM	10 to 1100
TS-537/TSM	75 to 1100
TS-330/TSM	1000 to 15,000
TS-683/TSM	10,000 to 75,000

(CI Meter TS-537/TSM listed above is expected eventually to be replaced entirely by TS-710/TSM.) For Government laboratory tests, the primary standard sets are generally used as the actual test reference circuit in which the crystal is inserted. This is not true in the case of production-line and quality-control tests to be made by manufacturers. Here, the Government furnishes primary standard test sets to a manufacturer only for the purpose of correlating the reference test circuits used by the manufacturer. Even the Government inspection tests of sample lots of crystal units are made with the manufacturer's reference sets and not with the primary standards. When initially obtaining his reference test sets, the manufacturer may build them himself, duplicating the primary-standard circuitry, or he may purchase Military Standard test sets in the commercial market. But the fact that such sets are used for routine tests in production control officially rules out their classification as primary standard sets.

PRIMARY LOAD-CAPACITOR STANDARD

2-79. For routine measurements, the load capacitor contained in each standard CI meter can be considered sufficiently accurate to use without special correlation with a primary standard. However, when precision measurements are required, or when any significant deviation in the calibration of the standard test set should seem to occur, there should be available an external precision standard capacitor with which the test set capacitor can be correlated. A suitable capacitor to serve as a standard is Precision Capacitor Type 722-D, General Radio Co., or its equivalent.

PRIMARY CALIBRATED-RESISTOR STANDARD

2-80. In order to check the accuracy of the calibrated resistors used in adjusting the crystal test sets, it is desirable that a precision r-f resistance standard be available. The standard should be adaptable for use in a radio-frequency bridge. For this purpose, it is generally convenient to employ a bridge circuit in which a precision resistor standard is incorporated in the design as a component part. See paragraph 2-108.

PRIMARY TEMPERATURE STANDARDS

2-81. The boiling and freezing points of distilled water, with due regard for the atmospheric pressure, permit more than ample precision as a primary standard for routine calibrations of the temperature measuring equipment. Normally, the absolute barometric pressure at the time of testing need not be noted—only the mean pressure for the local elevation above sea level.

Reference Standards

SECONDARY FREQUENCY STANDARD

2-82. In those areas not reached by WWV ground waves, the crystal frequency measuring equipment should include a secondary frequency standard capable of a relative stability of 1 part in 10^8 per day or better. A high-precision secondary standard is also desirable, of course, even when WWV signals are constantly available. But in this case, a standard of less stability, if correlated frequently with WWV, can be as dependable as a maximum-stability unit that is correlated only after long intervals of operation. It is the secondary standard that is used to control the periods of the known cycles against which those of the unknown signal are to be compared.

2-83. A large number of high-precision standards are available on the commercial market. Of these, one that appears the equal, if not the superior of any other in aging stability is the James Knights-Sulzer frequency standard, developed jointly by the James Knights Co. and P. G. Sulzer of the National Bureau of Standards. This standard is used in the development of USAF frequency standards to measure fractional deviations in frequency to an accuracy of 1 part in 10^9 per day. For this degree of precision two Knights-Sulzer standards are used and each, once turned on, are never turned off. The crystal frequency to be measured is checked against each standard and the standards checked against each other. The high precision obtainable is due in large part to the use of evacuated glass holders in the fabrication of the crystal units employed in the standards, and in the extreme care used in the cleaning stages. The aging data for a 1-mc standard operated continuously from a constant-emf mercury cell at the Knights laboratories showed a net frequency shift from 999,999.5 cps to 999,999.7 cps between November 27, 1953 and March 8, 1955. During this period the frequency fluctuated both above and below the starting frequency by amounts greater than the 2 parts per 10^7 indicated for the total period; so that although a tendency for neither a positive nor a negative aging drift is indicated definitely for long periods of time, the stability over shorter intervals must be assumed to be less than the long-term average. During a 2-month test by the Signal Corps, one crystal unit of the type used in the J.K. frequency standard exhibited a stability of 1 part in 10^8 per week; another unit, 3 parts in 10^8 per week.

2-84. Where reference standards with stabilities on the order of 1 part in 10^8 per day are satisfactory, a representative type is the 100-kc frequency standard, R-F Oscillator O-76/U, of the Western Electric Co. Signal Corps engineers report that the O-76/U oscillator, after aging, can be expected to have a frequency stability on the order of 1 part in 10^9 per day.

AUDIO-FREQUENCY REFERENCE STANDARD

2-85. The a-f reference standard is a variable interpolation oscillator that is used as a difference-frequency reference standard in measuring audio beat frequencies and as a frequency-deviation reference standard for calibrating the frequency-deviation meter and recorder. The conventional method of measuring radio frequencies is to mix the unknown signal with a harmonic (or a subharmonic, or a harmonic of a subharmonic) of the fundamental of the secondary frequency standard. A difference frequency in the audio range is obtained and compared with the output of the variable audio-frequency (interpolation) oscillator. The latter is adjusted until its frequency is equal to the unknown difference frequency. The tuning dial of the variable oscillator will have been calibrated to permit an interpolated reading of the difference frequency, which can then be added to or subtracted from the standard harmonic to give the unknown frequency. The variable oscillator will previously have been correlated with the frequency standard at one or more representative check points, in reference to which the v-f-o tuned frequency can be interpolated.

2-86. As a frequency-deviation reference standard, these calibrated check points of the interpolation oscillator are used in the correlation of the frequency-deviation meter and the frequency-deviation recorder prior to a temperature-run test.

2-87. The interpolated frequencies, of course, are not as accurate percentagewise as the crystal-oscillator standard; but if the measured difference frequency is an extremely small fraction of the unknown frequency, the error introduced by the interpolation oscillator can be expected to be of much smaller magnitude in terms of cycles per second than the normal deviations of the crystal standard. If precision measurements of the difference frequencies are required, it would be preferable to count the cycles with a frequency counter directly controlled by a crystal standard, or to zero-beat the difference frequency with a vfo that in turn is continuously monitored by a crystal-standardized counter. A representative audio frequency reference standard is the 0-to-5-kc Interpolation Oscillator Type 1107A, General Radio Co.

REFERENCE CRYSTAL TEST SETS

2-88. As explained above in the discussion of the primary standard test sets, crystal manufacturers employ reference standard test sets for production-line and quality-control tests. The reference sets are CI-meter circuits that duplicate those of the primary standards, but which are usually modified somewhat and probably removed from their cabinet to permit convenient installation on or under a testing table in a production line. These reference test sets are correlated periodically with the primary standard test sets by Government inspectors.

TEMPERATURE REFERENCE STANDARD

2-89. Normally a pyrometer is used as a secondary temperature standard for the purpose of correlating the cold box thermometer and other temperature gauges, and the crystal heating controls. The same pyrometer is also generally used as the indicator in measuring the crystal-unit temperature during a temperature-run test. The sensing element of the pyrometer can be a thermocouple or a thermistor, the latter being the more accurate since the temperature reading will be independent of the temperature of a room-temperature junction. Whichever is used, it should be mounted on the quartz plate of a dummy crystal unit in order to simulate as closely as possible the thermal parameters associated with the crystals being tested. The sensing element, being in series with the current windings of the pyrometer, causes the deflection needle to follow the temperature changes of the dummy crystal plate. A separate dummy crystal unit should be available for each type of crystal holder being used in the tests. Where greater precision is required than is normal for routine tests, the dimensions and mounting of the crystal in the dummy unit should closely simulate the dimensions and mounting of the crystal in the test unit. For this purpose, a dummy crystal unit should be available for each narrow range of frequencies for each type of crystal unit to be tested, instead of simply for each type of crystal holder. The pyrometer scale for each sensing element should be checked and correlated periodically against the primary standard (boiling water and/or ice water). The scale should be calibrated in degrees centigrade. If a thermocouple is used, the current meter should be a microammeter; if a thermistor is used, a 0—1-ma. meter could be used if the power dissipated in the dummy crystal unit does not exceed the drive level of the crystal being tested; but for minimum error, a microammeter is requisite, especially where very thin crystals are to be tested. Preferably the current meter will be a component part of a temperature recorder. A typical thermistor is the Ney Co. model used to measure the dummy crystal temperature in a heater designed by E. L. Minnich as a modification of a USAF-developed model. The thermistor is enclosed at one end of a sealed glass stem. Electrical connection is through two copper-wire leads. Approximately, the resistance varies from 2000 ohms at room temperature to 400 ohms at 90°C. The dummy unit and the test unit are mounted side-by-side in the heater. For greater thermal contact with the dummy crystal blank, and hence for less lag in the temperature readings, the Frequency Control Group at WADC employs a platinum-wire thermistor wrapped around the dummy blank. The WADC heater designed by D. J. Theobald, is 1.5 in. diameter slug, 2.5 in. long which mounts the test crystal unit in one end and the dummy unit in the other.

REFERENCE LOAD CAPACITORS

2-90. The calibrated capacitor used as a standard for simulating the rated load capacitance of a parallel-mode crystal unit will be a component part of the CI meter used as a reference test set. Thus, it does not have to be supplied separately unless the test circuit is being constructed locally. A typical load capacitor is a calibrated, variable, single-section, air-dielectric unit with a range of 5 to 100 $\mu\mu$f.

REFERENCE CALIBRATED RESISTORS

2-91. A set of calibrated r-f resistors which covers the effective-resistance range of all Military Standard crystal units to be tested must be available for use with those test sets which are not provided with an internal calibrated resistor set. The calibrated resistors do not have to be precision standards, but they should have short leads and be composition (noninductive) types with tolerances of their nominal values not greater than plus or minus one per cent. The same resistors can be used in both the primary standard test sets and in the manufacturer's reference test sets. For test set adjustments of the drive level for crystal units of maximum effective resistance, it would be convenient to have available a set of maximum-resistance resistors mounted on crystal-holder plug-in bases. The standard Armed Services CI meter, TS-330/TSM, and also the limited-standard model, TS-537/TSM, are internally provided with calibrated decade resistor circuits and appropriate switching controls. External resistors are required for use with the standard CI meters, TS-710/TSM (which is replacing the TS-537/TSM) and TS-683/TSM.

Indicating and Recording Instruments

FREQUENCY COUNTER OR METER

2-92. Certainly, the quickest method for measuring a frequency with reasonably good accuracy is to feed the unknown signal to the input of a frequency counter and read the frequency directly. Representative units used in the crystal industry at the present time are the crystal-controlled counters developed by the Hewlett-Packard Co. Typical models are the 5-digit 522B and the 8-digit 524B. The principle of operation of these counters is essentially the same as that used by a doctor in measuring a pulse rate. It is not the frequency that is counted, but the number of pulses during a given length of time. A crystal oscillator is used as a time standard to measure accurately a given length of time, serving the same purpose as the doctor's watch. (The crystal standard provided with the Hewlett-Packard counter type 524A is reported to have an accuracy of 2 parts in 10^6 per week—for greater accuracy, input controls are incorporated to permit the use of an external frequency standard.) The crystal timing circuit controls a fast-acting flip-flop electronic gate. When the gate is open, the input cycles of the frequency to be measured are passed through to a counting circuit. The gate-controlling circuit can be adjusted to keep the gate open for crystal-controlled intervals of 0.001 second to 10 seconds. If, for instance, the gate is open for one second, the number of input cycles passing through will equal numerically the unknown frequency. It is the problem of the counting circuit to count the cycles accurately. The counting is performed by a sequence of cascaded decade scalers, each of which operates its own indicating system. Each scaler generates one output pulse for every ten input pulses to the circuit. The first scaler divides the input cycles by ten and feeds its output to the second scaler. The second scaler divides by ten again, and passes its output on the third decade scaler. And so on to the last scaler. When the gate is closed, each scaler indicates by a neon lamp a digit representing the number of pulses it has just received from the preceding scaler which have not been passed on to the succeeding scaler. (In the H-P 524B, the first two scalers indicate by meters.) In other words, each scaler effectively counts all the pulses it receives, divides by ten and passes the quotient on to the next scaler to count, and then shows the remainder by lamp light on the front panel. The observer can thus read the frequency directly. A decimal point is automatically positioned to give the reading in kilocycles. Before opening the gate for the next count, the gate flip-flop circuit resets the counting circuit. The counting accuracy is $\pm$ 1 count, or a maximum of 1 part in 10^d, where d is equal to the number of digits shown. The frequency range of a single counter, without accessory circuits, is 0 to 10 mc. The addition of plug-in units can extend the range to 220 mc. A plug-in amplifier unit permits an increase in input sensitivity from 1 volt rms, minimum, to 10 millivolts rms, minimum. By using the unknown frequency to control the electronic gate and feeding the frequency standard to the input, the counter can be used to measure the period of the unknown signal in seconds, milliseconds, or microseconds, with the decimal point automatically positioned. A counter also permits a ready method of utilizing WWV sky-wave signals as a primary standard having almost the same dependability as is possible with WWV ground signals. Since the random frequency deviations of the sky wave can be expected to average out over a relatively long period of time—a second is a sufficient interval, except possibly in times of severe ionospheric storms—the WWV sky signals can be received, amplified, and divided (if necessary) for use as a timing standard to control the electronic gate of a counter at intervals of 1 second or greater. With the one-second intervals as measured by the sky wave practically as accurate as those of the ground wave, the counter can thus be used to give a precision reading of the local secondary standard frequency and permit its correlation with the WWV primary standard. The total accuracy, of course, cannot be greater than the counting accuracy, which, in turn, increases by a factor of 10 for each digit shown. For a counting accuracy between 1 part in 10^8 and 1 part in 10^9, a minimum of 8 digits must be indicated in the counter reading.

2-93. Other types of frequency meters in widespread use are those of the older heterodyne v-f-o type. The variable-frequency oscillators are periodically calibrated at standard-frequency check points. The unknown signal is mixed with the v-f-o signal, the latter being varied until a zero beat is obtained. The beat note can be indicated either aurally or visually. With precision dialing of the vfo and careful interpolation between the standard harmonic check points, quite high accuracies can be obtained. The closer the check points, the nearer the measuring accuracy approaches the accuracy of the check-point standard. With a visual (oscilloscope) indication of the null heterodyne point this approach can be quite close. The average v-f-o heterodyne frequency meter, nevertheless, is less accurate than those measuring systems that employ the frequency standard, itself, to heterodyne directly with the unknown frequency. Representative heterodyne frequency meters are Frequency Meter FR-4 and Frequency Meter Set SCR-211( ).

2-94. Direct-reading frequency meters employing frequency-divider circuits, which can be calibrated against (but not controlled by) frequency standards, are also in use. The precision of such meters is generally not satisfactory for any but low-frequency crystal measurements. In the audio range such meters are quite useful. (See Frequency-Deviation Meter, paragraph 2-96.)

2-95. As for the use of wavemeters, they are entirely too inaccurate for ordinary crystal measurements. Such meters, being little more than a tuned series circuit with a resonance indicator, are, of course, relatively inexpensive and easy to construct. For very-low-frequency measurements, where broad tolerances are permissible, a wavemeter conceivably could find a useful application if the expense of a more accurate meter is unwarranted.

FREQUENCY-DEVIATION METER

2-96. The frequency-deviation meter is a conventional electronic frequency meter to be correlated with the interpolation oscillator. Its principal purpose is to provide a direct reading of the difference frequency obtained when the frequency of the crystal under test is mixed with the standard test frequency. Since the difference frequency that would result if the crystal frequency equaled its nominal value is known, the frequency deviation is readily measured as the difference between the actual meter reading and the hypothetical nominal reading. The frequency-deviation meter should also provide an adjustable d-c output for feeding the frequency-deviation recorder.

2-97. The input signal to a typical electronic frequency meter is first amplified to a given level and limited so that each cycle has a predetermined amplitude. A counting circuit follows, which serves to trigger a current pulse of fixed charge that flows through the meter windings. The meter reading will thus be directly proportional to the number of current pulses per second, which in turn will be directly proportional to the number of input cycles per second.

2-98. A representative frequency-deviation meter is the Hewlett-Packard Frequency Meter Type 500A or 500B. The latter has a range of 0 to 100 kc; the former extends only to 50 kc. A phone jack on the panel permits connection to a 1-ma., 1400-ohm frequency-deviation recorder. The input sensitivity is 0.2 volt rms, minimum.

FREQUENCY-DEVIATION RECORDER

2-99. An automatic recorder is required to provide a graphical record of the deviation in frequency as the temperature of the crystal unit being tested is made to vary over the rated operating range. As a strip of graph paper uniformly unwinds, a stylus, or an equivalent device, is actuated by an input from the frequency-deviation meter in such a way that the frequency measurements are continuously recorded on the graph. Additional current pulses at regular temperature intervals from a temperature recorder can serve to calibrate the abscissa of the graph in degrees centigrade. Before testing each type of crystal unit at a given frequency, the recorder must be correlated with the frequency-deviation meter and the temperature recorder. A representative ammeter recorder is the Esterline-Angus Automatic Recorder Model AW, which has a 1-ma. (dc), 1400-ohm (plus or minus 100 ohms) input.

OSCILLOSCOPE

2-100. The oscilloscope is used to provide a visual check when correlating the interpolation oscillator against a crystal standard, and when measuring a difference frequency with the aid of the interpolation oscillator. For either of the above uses, the horizontal plates of the oscilloscope are connected to the output of the interpolation oscillator and the vertical plates are connected to the output of the receiver. The operator adjusts the interpolation oscillator to obtain a fixed image on the screen, at which point he can either calibrate the interpolation oscillator against a known receiver output, or interpolate an unknown receiver output from the oscillator calibration. A representative oscilloscope is the Dumont Type 241.

GRID-CURRENT METER

2-101. All standard Armed Services CI meters are equipped with a front panel grid-current meter except the TS-710/TSM, which is provided with a vacuum-tube voltmeter. For the reference test sets not provided internally with a grid-current meter, an external meter must be provided. The meter is used principally in correlating the grid excitation of the reference circuit with the effective resistance of the crystal unit. It is then used to correlate the effective-resistance recorder against the reference grid-current levels for maximum specified and minimum expected values of resistance. A representative meter is the JAN type Meter MR26W200DCUA (0 to 200 μa).

EFFECTIVE-RESISTANCE RECORDER

2-102. A recorder is used in the testing of Military Standard crystal units to automatically plot on graph paper the deviations in crystal resistance as the temperature is varied over the operating range. The recorder stylus is to be actuated by the d-c current in the grid circuit of the reference test set. If the recorder is sufficiently sensitive, the grid current may be used directly; otherwise a d-c amplifier should be employed. The minimum grid current, and hence the minimum excitation of the recorder, occurs when crystal units of maximum resistance are being tested. By previously correlating the recorder with the maximum-resistance grid-current level, the graphical record will indicate whether the resistance of any crystal unit exceeds the rated maximum at any temperature. By also feeding the effective-resistance recorder input pulses from the temperature recorder at regular temperature intervals (every 5 degrees centigrade is normal), the abscissa of the resistance graph will be calibrated in temperature degrees. A recorder of the Esterline-Angus type, described in paragraph 2-99 as representative of the models satisfactory for recording the frequency deviation, is also satisfactory for recording resistance deviation; but a d-c amplifier might be required to provide the necessary sensitivity. A representative recorder sufficiently sensitive to operate at the microampere level is the 0-to-5-μa Photoelectric Recorder Model 8CEIELIB-1 of the General Electric Co.

ELECTRONIC A-C VOLTMETER

2-103. An a-c voltmeter is required to measure the voltage across the crystal units under test when determinations of the drive level are desired. Care must be taken that the voltmeter causes no significant imbalance or disturbance of the tuned CI-meter circuit. Because of the extreme sensitivity of the test circuits, particularly at the higher frequencies, conventional a-c voltmeters are not satisfactory for such measurements. Only those meters of maximum input impedance and sensitivity should be used. Even then, unless the voltmeter circuit is a differential type, the voltmeter leads should not be connected directly across the crystal unit, as the unmatched impedances to ground of the two leads can cause the test-circuit frequency—and hence the crystal impedance and voltage—to change. The proper method would be to measure the voltage from each crystal-unit terminal to ground separately, making certain that the act of measurement does not in itself change the test frequency of the crystal. The voltage across the crystal unit, of course, is equal to the difference between the two measured voltages. Suitable vacuum-tube voltmeters are the equivalent of Multimeter TS-505/U or the Hewlett-Packard Electronic Voltmeter Model 410B. To be preferred would be a differential vacuum-tube voltmeter such as Voltmeter ME-56 ( )/TSM. (The ME-56( )/TSM should not be used above 60 mc unless special calibration procedures are employed.)

DUMMY-CRYSTAL-UNIT PYROMETER

2-104. This is the same pyrometer that is described above as a secondary reference standard used in the correlation of the other temperature indicators and controlling devices. It is also used during the temperature-run tests as an indirect indicator of the crystal-unit temperature at each instant. The sensing element (thermistor, preferably, or thermocouple) is mounted on the crystal plate in a dummy crystal unit simulating the holder and construction of the crystal unit under test. The heater, which mounts the test crystal during the temperature run, should provide an equivalent mounting position for the dummy unit. The temperature thus indicated by the pyrometer can then be considered a reasonably close approximation to the simultaneous mean temperature of the test crystal.

COLD-BOX THERMOMETER

2-105. Except when mass quantities on a production line are being tested, it is usual for only one crystal unit to be tested during a temperature run. For this purpose a thermostatically controlled cold box is adequate for cooling the crystal unit to the low-temperature limit. When the temperature run for an individual unit is ready to begin, the unit is removed and mounted in a heater. To make certain that the temperature of the cold box is correct, a thermometer must be provided which has previously been correlated with the pyrometer reference standard. The cold-box thermostat is then adjusted to maintain the correct reading on the thermometer.

2-106. When multiples of perhaps a dozen crystal units are to be given a temperature-run test simultaneously, the cold box and heater are usually replaced by a single chamber which can be cooled and heated as desired by a thermostatically regulated air stream. Even so, a thermometer periodically correlated with the reference pyrometer should be in view to give an accurate indication of the crystal chamber temperature when making thermostatic adjustments and starting a temperature run. Any medium-precision mercury thermometer, such as those used by chemists in measuring reaction temperatures, is satisfactory, provided the calibrated scale covers the necessary temperature range.

Q METER

2-107. A Q meter is required for calibrating the reference test load capacitors against the precision standard. The Q meter should be equipped with a standard inductance coil. A representative model is Q Meter TS-617( )/U.

R-F BRIDGE

2-108. An accurate r-f bridge is required in the correlation of the calibrated resistors used as references when measuring the effective resistance of crystal units and when adjusting the test sets to suitable drive levels. The standard resistors, against which the reference resistors are to be checked, are preferably component parts of the r-f bridge. A satisfactory bridge would be the equivalent of R-F Bridge Navy Type No. 60094.

EARPHONES OR LOUDSPEAKER

2-109. Earphones and/or a loudspeaker are desirable as frequency indicators when rapid frequency checks are to be made and neither recordings of temperature runs nor great precision is required. Audio measurements, made by zero-beating the crystal frequency against a known frequency, are particularly suited to certain production-line stages. For example, when plating or etching a crystal to frequency, an audio check is usually the simplest procedure to ensure that the crystal does not overshoot its mark. In laboratory tests, the radio receiver speaker has many uses, such as providing the aural check when zero-beating the secondary frequency standard against WWV signals.

Auxiliary Amplifiers and Frequency Converters

RADIO RECEIVER

2-110. A cw-mcw receiver is required for the reception of WWV signals and for use as a band-pass amplifier, mixer, detector, and audio amplifier of the various signals used in the measurement of crystal frequencies. Other than its use as an r-f amplifier of the antenna signals received from WWV, the receiver serves chiefly as a mixer-amplifier of the standard frequency and the unknown frequency, and as the detector and amplifier of the resulting audio beat frequency. The r-f tuned circuits, of course, also perform the function of filters in rejecting the amplification of all but the desired band of input frequencies. For fast, approximate checks of frequency adjustments, such as when initially tuning a test set to a given nominal frequency, the receiver can be tuned to the desired frequency, the bfo turned on, the output indicated by an audio or visual indicator, and the oscillating circuit adjusted to a zero beat. For low-frequency measurements, Radio Receiver BC-342( ) or BC-348( ) or an equivalent is satisfactory. For higher frequencies, a receiver such as the Hammarlund Model SP-600, with a range from 0.55 to 54 mc, is adequate.

HARMONIC GENERATORS

2-111. Other than a precision secondary frequency standard, a crystal-test laboratory generally has the need for a number of auxiliary frequency generators and harmonic multipliers. For some purposes, these generators, although requiring crystal control, need have only a medium degree of stability—a few parts in 10^5 being sufficient. For example, in correlating a reference load capacitor with the precision standard capacitor, a 400-kc crystal-controlled generator of medium stability is desirable for use with the Q meter. Such a generator could be a Signal Generator TS-497/URR, or its equivalent. Generally, for multipurpose work, a frequency generator is preferred that can be switched from medium-precision internal control to high-precision external control when harmonics of the precision standard are required. When a harmonic generator is controlled by the principal frequency standard, the output of the harmonic generator in effect becomes the frequency standard with which the measurements of the unknown frequency are to be made. Although it would be desirable to have selector circuits so that all harmonics are rejected except the particular one selected, such a degree of perfection is not economically practical except where the utmost precision is to be combined with maximum speed of measurement. Nevertheless, harmonic generators of this nature are commercially available. (See the discussion of the Plessey Frequency Synthesizer in Section I.) The harmonic generators most generally found in crystal-test laboratories do not provide sine-wave outputs, but outputs rich in all harmonics simultaneously. Where subharmonics, and harmonics of the subharmonics, of the precision standard are required, the harmonic generator must be designed for frequency division of the controlling standard—that, or else a separate frequency divider must be provided for installation between the standard and the harmonic generator. When the fundamental of the harmonic-generator output is the fundamental of the frequency standard, the generator design need consist of no more than conventional untuned class C amplifiers or multivibrators. When the fundamental of the harmonic-generator output is to be a higher multiple of the standard fundamental, tuned amplifier-multiplier stages must precede the final harmonic-generator output amplifier. If the tuned-multiplier circuit is not an inherent part of the harmonic-generator unit design, the circuit must be supplied separately.

2-112. For the calibration of the audio-frequency interpolation oscillator, a 1-kc harmonic generator is desirable but not necessary. A 10-kc harmonic generator can be used for calibrating the a-f oscillator just as easily, and at the same time provide a standard harmonic sequence for measuring low and very low frequencies. For this latter purpose, as an aid in identifying the exact multiple of 10 kc by which a given beat frequency is obtained, it is helpful, but not mandatory, that the same unit be capable of generating harmonics of 9 kc and 11 kc. A harmonic generator providing 9-10-11-kc outputs is the CV-118, developed by the Washington Institute of Technology.

2-113. The principal function of a 10-kc harmonic generator as a frequency standard is to ensure that, on mixing its output with the unknown signal, one of the resulting difference frequencies will be not greater than 5000 cps, and hence can be measured to an accuracy of a cycle per second or better with the aid of an interpolation oscillator and an oscilloscope, and to a somewhat lesser accuracy with a frequency-deviation meter and/or a recorder.

2-114. When frequencies are to be measured that are higher than the useful harmonic range of the 10-kc generator, they can be reduced to the 10-kc-harmonic range by frequency division, or by heterodyning with a higher-frequency standard to obtain a low difference frequency, which, in turn, can be mixed with the 10-kc harmonics to obtain a difference frequency in the a-f range. The latter method of mixing the unknown frequency first with a high-frequency standard and then with a 10-kc harmonic does not necessarily require two separate mixing stages. The 10-kc harmonics and the higher-frequency harmonics can be mixed simultaneously with the unknown. A receiver is used to detect the audio beat note. It is only necessary that the mixing circuit precede the superheterodyne mixing stage of the receiver; otherwise the beat note will follow all variations of the receiver local oscillator. For example, the standard frequencies should not be used to replace the b-f-o frequency of the receiver, unless the receiver happens to be a tuned r-f type.

2-115. Now, if a given harmonic of 10 kc permits an audio beat frequency of f_1, an adjacent harmonic will provide another audio beat note equal to 10 kc minus f_1. The beat note of interest is the one less than 5 kc. To restrict all higher beat frequencies, the receiver should be provided with a low-pass audio filter in the output with a sharp cutoff at 5 kc. In the event that the two lowest beat frequencies are both approximately equal to 5 kc, the 9-kc or 11-kc harmonics should replace the 10-kc standard.

2-116. The principal frequency standard probably will have a fundamental of 50, 100, or 200 kc, with the 100-kc fundamental being the most common. Harmonics of the low-frequency standard can be mixed with the 10-kc harmonics for measurements in the medium-frequency range and in the high-frequency range up to 10 mc, if desired. Generally h-f harmonics will be present in the principal frequency-standard output in sufficient strength that an external multivibrator or other type of harmonic generator, other than the 10-kc unit, is not required. However, if an external harmonic generator is necessary, it may well be that greater equipment efficiency can be attained if a generator fundamental higher than that of the principal frequency standard is employed.

2-117. If a multivibrator is used to generate the 10-kc signal, its useful harmonic range will normally extend as far as the 100th harmonic. Beyond this, unless frequency division of the unknown frequencies is to be used, a 1-mc harmonic generator can be used. The useful harmonic (not frequency) range of the 1-mc generator is generally much less than an equivalent 10-kc generator, since the higher harmonics are in the v-h-f spectrum and hence are more rapidly attenuated by distributed circuit losses. Thus, for the measurement of vhf's, if frequency division is not employed, a harmonic generator of 10, 15, 20, or 25 mc should also be available. A representative 1-mc harmonic generator is the JAN type CV-119, or its commercial equivalent, Frequency Generator RA-35134, developed by the Washington Institute of Technology. A representative generator of high frequencies is the 15-20-25-mc frequency generator, JAN type CV-122, manufactured by the Reeves-Hoffman Co.

FREQUENCY DIVIDER

2-118. Where the frequency to be measured is higher than the range of the receiver, one of two means can be employed to lower the frequency of the unknown signal. The first is to heterodyne the unknown frequency with a known standard so that a difference frequency in the radio range of the receiver is produced. The difference frequency can then be measured by conventional methods. The original unknown frequency can thus be computed from the measured difference frequency and the heterodyne standard. The second method is to divide the unknown frequency by a known amount, and then to measure the quotient frequency. Frequency dividers designed as separate units specifically for reducing unknown frequencies to more easily handled lower frequencies do not appear to be readily obtainable at the present time, at least, their availability is not widely advertised. However, there are available counter units, principally of the decade type, which can be used in frequency-measuring systems as frequency dividers. But such dividers are not available in the v-h-f range where they would be of most use. Free-running multivibrators which can be adjusted for synchronization at a subharmonic of the unknown frequency are probably the most effective method of frequency division of very high frequencies. A lock indicator meter should be provided which will show a sharp peak when an appropriate stage is tuned to synchronization with the control frequency. Although measurements of considerable accuracy can be made using frequency division, greater accuracy in the v-h-f range is generally possible if the conversion to a lower frequency is accomplished by the heterodyne method.

VARIABLE-RADIO-FREQUENCY OSCILLATOR

2-119. An r-f oscillator continuously variable over the expected crystal-test range is always useful if rapid frequency checks are to be made and the accuracy does not have to be of the utmost precision. A vfo is particularly applicable when testing unfinished crystals along a production line. The frequency of the crystal unit under test is mixed directly with the v-f-o output, and one or the other is adjusted until a zero beat is obtained. Some method must be employed to check the accuracy of the known v-f-o frequency against a standard. This can be done periodically by crystal calibration, or continually by employing a crystal-timed counter. The vfo can be any standard signal generator of suitable range, such as Signal Generator TS-497/URR, for example.

R-F AMPLIFIER

2-120. R-f amplifiers are required as separate units wherever the r-f output from one equipment is not sufficient to provide the input level required by succeeding equipment. Such amplifiers are most likely to be required for boosting the inputs to counters, frequency meters, harmonic generators, frequency dividers, and the like, particularly where relatively long cable distances are involved and the frequencies are high.

D-C AMPLIFIER

2-121. A d-c amplifier will be required if the d-c input necessary to properly activate a recorder is greater than that supplied by the respective sensing circuit. Where a d-c amplifier is most likely to be needed is to boost the input to the effective-resistance recorder, which, if not of microampere sensitivity, cannot provide a full-scale recording if activated directly by the grid current of a reference test set.

SIGNAL CONTROL PANEL

2-122. A central switching panel should be available for facilitating the control of all the r-f equipment used in the crystal testing system. Controls should be provided to permit any desired heterodyning and routing of the outputs of the various frequency sources to be used in the tests. Attenuators and a mixer circuit are normally incorporated in the panel design. Such is the design of the CV-120 mixing and switching panel. Switches are provided for selecting the appropriate CI meter, for selecting the signal from the appropriate frequency generator, for selecting attenuators for each signal, and for directing the output of the mixer to the receiver. Great care must be taken in the design of the control panel and the entire r-f signal system to provide adequate shielding of all circuits, and adequate r-f filtering of all power leads. If this is not done, stray frequencies will find their way into the radio receiver to confuse the measurements. It is also important that the signal levels be of relatively low amplitude. The control panel should be provided with suitable attenuators and amplitude controls.

Auxiliary Test-Control Devices and Test-Plant Fixtures

2-123. In the list given in paragraph 2-67 for equipments used in measuring frequencies, these items classified as *Auxiliary Devices for Controlling Crystal Unit Test Conditions* and as *Test-Plant Fixtures,* if not self-explanatory, are described functionally in the discussions of related test procedures and equipments: and so, will not be discussed additionally at this point.

FREQUENCY-MEASURING SYSTEMS FOR TESTING CRYSTAL UNITS

2-124. Figures 2-88 to 2-94 illustrate by block diagrams a number of frequency-measuring systems commonly used in laboratories and manufacturing plants. For the reader who has followed the foregoing discussion of the equipments used, the illustrations should require only brief explanations.

Heterodyne-Frequency-Meter System

2-125. Figure 2-88 shows the system for measuring crystal frequencies with a heterodyne type of radio-frequency meter and earphones (or speaker). In the decade preceding World War II this method was by far the most commonly used for making relatively precise frequency measurements. The test frequency and the output of the r-f vfo are heterodyned in the r-f mixer. The coupling to the mixer from both frequency sources must be extremely loose so that the act of mixing the frequencies does not significantly affect the tuning of the respective circuits. The precision tuning dial of the vfo is adjusted until an audio beat note is detected and heard in the earphones. The vfo is further adjusted until a zero beat results. The adjustment region of the tuning dial in which no signal can be heard is approximately 40 cps wide, 20 cycles on each side of the true zero beat at the center. The true zero beat, which occurs when the v-f-o frequency exactly equals the unknown frequency, must be interpolated as the halfway point between those dial settings at which the operator can just hear an audible note, which occurs at approximately 20 cps for the average person. By this method, an experienced operator can match the two frequencies to within 1 or 2 cps when no other sound but the beat notes can be detected. However, since

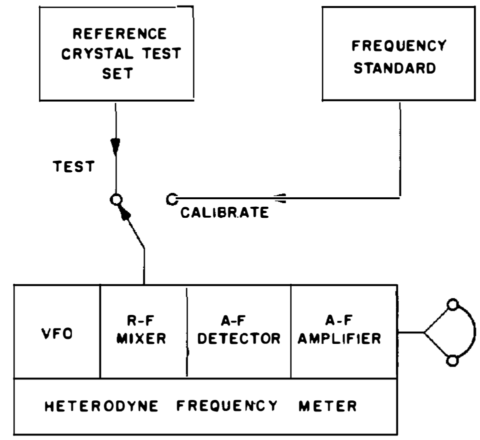


Figure 2-88. *System for measuring crystal frequencies aurally with heterodyne frequency meter*

there is usually some noise or hum in a heterodyne frequency meter which will wax and wane with a slow beat note, it is often possible to detect directly beat frequencies of less than 1 cycle per second. This is more likely to be possible when detecting a beat note between two audio signals than between two radio signals, since the audio circuits of a radio-frequency vfo are less likely to respond to the extremely low modulation frequencies than are the circuits of an audio-range interpolation oscillator.

2-126. With the use of a tuning fork, resonant, for example, at 256 cps, the vfo can be adjusted to produce 256-cps audio outputs on each side of the null region. That the heterodyne meter is producing exactly 256 cps can be detected by the zero beat between the tuning-fork vibrations and the audio note from the earphones. The use of the tuning fork permits a more precise determination of equal audio frequencies on each side of the r-f-circuit zero beat, the dial point of which will be the exact center between the two 256 cps beat-note settings. The frequency of the vfo at the zero-beat dial setting is to be interpolated from previous calibrations of the vfo.

2-127. The nearest crystal-standard check point on each side of the measured dial setting should be rechecked against the appropriate harmonic from the frequency standard, either immediately before or immediately after the measurement of the unknown frequency is made. The radio frequency corresponding to the measured dial setting is then interpolated between the two adjacent check points by assuming that the differences in frequency are in the same ratio as the differences between the respective dial settings. For example, if the measured dial setting is exactly one-half the distance between the dial settings corresponding to two known harmonics of the standard, then the measured frequency lies halfway between the two harmonics.

2-128. In calibrating the frequency meter against the standard, the output from the standard is coupled to the r-f mixer, the vfo is adjusted for a zero beat, and the dial setting at the center of the null region is determined in exactly the same way as when measuring an unknown frequency. The fact that the frequency in this case is known to equal a standard harmonic permits the measured dial setting to be calibrated as the dial point corresponding to the given frequency. In using the frequency standard in calibrating the heterodyne meter, or in any other frequency-measuring use, care should always be taken that the standard is given sufficient time to reach its equilibrium operating temperature. At least one hour, and preferably two hours, depending upon the precision required, should be allowed for the unit to warm up after a period of inoperation. If frequently used, the standard should be energized continuously throughout its lifetime. The frequency standard used with the heterodyne frequency meter need not be of top precision. A stability of 1 part in 10^5 is sufficient, since greater accuracy than this generally cannot be achieved in correlating and interpolating the radio-frequency dial settings.

Frequency-Reading Counter System

2-129. The system shown in figure 2-89 employing a direct-reading frequency counter is largely self-explanatory. The frequency standard is employed to time the counting intervals. The r-f amplifier may be required, since the input voltage to the counter usually must be on the order of 1 or more volts rms—a voltage level requiring a closer coupling to the CI meter circuit than should be permitted. The accuracy of the counter readings can be no greater than the number of significant digits shown on the counter scale makes possible. If six digits are shown, the maximum theoretical accuracy of 1 part in the 6-digit integer indicated can be assumed if the possible error introduced by the timing frequency standard is very small by comparison and the counting circuit can be depended upon not to skip a count. If the error introduced by the frequency standard is on the same order as the limitations of the counting circuit, the total tolerance for error must be the sum of the tolerances of the two error sources. The use of an r-f amplifier reduces the possibility of a random counting error, particularly if the amplifier is equipped with an a-g-c circuit to maintain the output amplitude constant against variations in the input amplitude.

VFO-Counter System

2-130. The measuring system shown in figure 2-90 employing a vfo and a counter is particularly useful for individual room-temperature tests of crystal units on a production line. The measuring method is fundamentally similar to the heterodyne-frequency-meter method illustrated in figure 2-88. The principal difference is that the frequency of the vfo is not interpolated from a calibrated crystal-checked scale, but is read directly on the

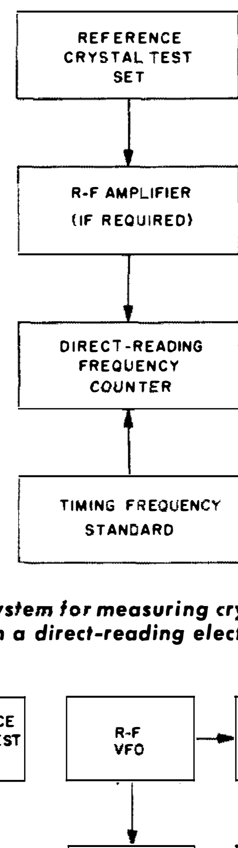


Figure 2-89. System for measuring crystal frequencies visually with a direct-reading electronic counter

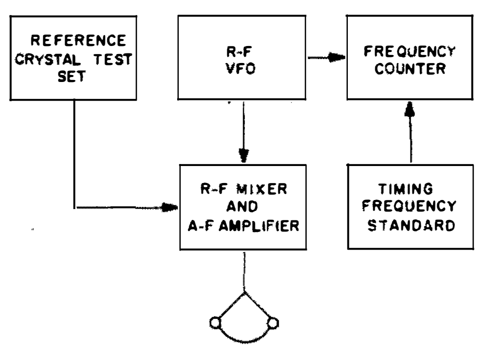


Figure 2-90. System for measuring crystal frequencies aurally with a variable frequency oscillator that is visually monitored by a direct-reading electronic counter

frequency-counter indicator. The system is especially useful when bringing a crystal plate by one process or another to a desired frequency. The vfo is set at the desired frequency and the crystal fabrication process is continued until the crystal can produce a zero beat in the phones or a speaker. When testing odd assortments of crystals which require that the v-f-o frequency be changed and checked often, the use of the frequency counter is a great time-saver over the crystal check-point method. Since a counter reading of the v-f-o frequency can be obtained almost instantly, the same counter can be shared by a large number of crystal testers simultaneously if placed in a position within view of all, and if the proper switching facilities are provided. If necessary, an r-f amplifier can be installed to boost the input to the counter.

Double-Heterodyne System for Precision V-H-F Measurements

2-131. Figure 2-91 illustrates a typical system for obtaining relatively precise measurements in the h-f and v-h-f ranges. Two stages of heterodyning are employed. The first stage converts the unknown crystal frequency into another unknown frequency within the tuning range of the receiver. This second unknown signal, which in the figure is assumed to lie between 5 and 15 mc, is mixed in the second stage with the nearest harmonic combination of 100 kc and 10 kc to produce an unknown difference frequency in the audio range lying between 0 and 5000 cps. The audio frequency is detected by the receiver (operated mcw) and fed to the vertical plates of an oscilloscope. To the horizontal plates of the oscilloscope is fed the audio output of the interpolation oscillator, whose frequency is adjusted until a reasonably stationary ellipse is obtained on the scope. At this point it can be assumed that the frequency of the interpolation oscillator is equal to the frequency of the receiver output. As the name implies, the interpolation oscillator frequency is determined by interpolation between adjacent calibrated check points. Adjustment of the interpolation oscillator to match the receiver output with the aid of an oscilloscope permits a more accurate measurement than if the measurement is performed aurally with the aid of a loudspeaker or earphones.

2-132. If the unknown frequency in each of the two stages of heterodyning is greater than the respective standard with which it is mixed, the original unknown can be computed as the sum of the mixing standards and the interpolation-oscillator frequency. In general, the unknown input frequency of either stage will be equal to the respective harmonic standard with which it is mixed plus or minus the resulting difference frequency. The initial frequency is computed by starting with the final heterodyne stage in which the difference frequency is directly measured. Because this directly measured frequency is in the low

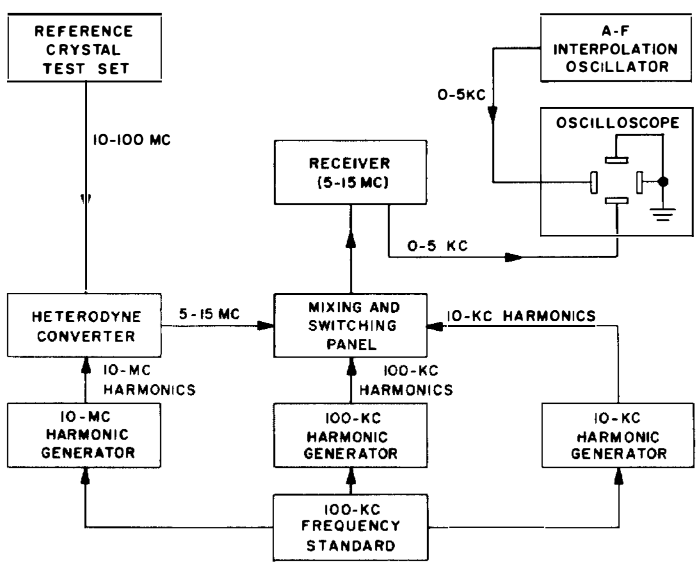


Figure 2-91. System, employing a heterodyne converter, for measuring h-f and v-h-f crystal frequencies visually with an oscilloscope and a-f interpolation oscillator

audio range, it represents a very small percentage of the whole, so that the errors made in interpolating its value can usually be considered negligible in estimating the total frequency. The tolerances to be allowed in the measured value of the crystal frequency are essentially the same as those of the 100-kc frequency standard.

Government Inspection System for Room-Temperature Crystal Tests

2-133. Figure 2-92 shows by block diagram a general system for testing crystal frequencies as recommended for U. S. Government inspection tests. The system is essentially the same as that described in the foregoing paragraph and illustrated in figure 2-91. In place of the first heterodyne stage of figure 2-91, figure 2-92 shows a frequency divider. In an actual inspection test, if the frequency under test must be reduced, either a divider or a heterodyne converter can be used, according to the facilities available. The loudspeaker in figure 2-92 is used as an aid in identifying the particular harmonic being mixed with the frequency under test and in correlating the secondary frequency standard against WWV. If the tuning of the crystal test set is adjusted slightly so that the crystal frequency increases, the rise or fall in the pitch of the speaker signal will indicate whether the test frequency is, respectively, higher or lower than the mixing harmonic. If multivibrator dividers are used, each stage should be tuned separately to lock with the control frequency, as indicated by a sharp peak on the lock indicating meter.

Government Inspection System for Temperature-Run Crystal Tests

2-134. Figure 2-93 shows a generalized block diagram of the system recommended for U. S. Government inspection tests of crystal units when the operating temperature is made to vary over its specified range. Insofar as the instantaneous measurements of the crystal frequency is concerned, using the oscilloscope and interpolation oscillator, the system is exactly the same as that described in the previous paragraph for room-temperature measurements. The additional features are the two recording circuits—one for recording the frequency deviation vs the temperature, the other for recording the effective-resistance deviation vs the temperature. The same audio output from the receiver that can be applied to the oscilloscope is applied to the input of the direct-reading low-frequency meter. The meter converts the audio input into a direct current proportional to the frequency. The d-c control signal, in turn, operates the frequency-deviation indicator of the meter and the stylus of the graphical

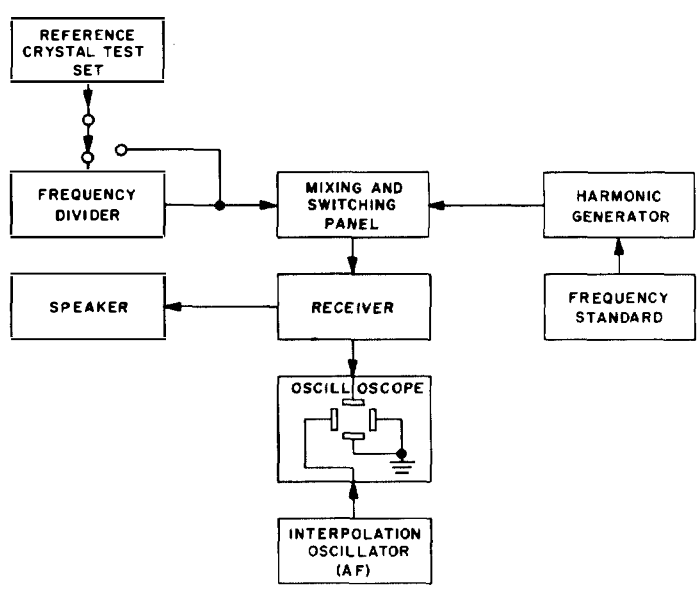


Figure 2-92. System recommended for Government inspection measurements of crystal frequencies at room temperature. The measurements are made visually with the oscilloscope and interpolation oscillator. The speaker is used principally as an aid in determining whether the crystal frequency under test is greater or less than the standard harmonic

recorder. The variations in the control current are thus indicated as deviations in the frequency as the test proceeds through the full temperature run. Similarly, the d-c grid current of the crystal test set is used as a control current to indicate fluctuations in the effective resistance of the test crystal unit. This current directly, or through a d-c amplifier, controls the stylus of the effective-resistance graphical recorder. During the tests, the rate of change in temperature must be under control so that its value at any point in a recording can be interpolated accurately.

Frequency Measuring System at WADC

2-135. Figure 2-94 shows by block diagram the specific system of equipment used at Wright Air Development Center for testing preproduction crystal units. The fundamental system is the same as that shown in figure 2-93. The equipments used are among those mentioned as representative units in the equipment descriptions of paragraphs 2-67 through 2-123.

PROCEDURE FOR CORRELATING TEST EQUIPMENT WITH STANDARDS

2-136. Before the actual testing of a crystal unit begins, the various reference standards must be correlated with the primary standards, and the indicators and recorders must be correlated with the reference standards. In the *Inspection Manual for Crystal Units, Quartz,* the Armed Services Electro-Standards Agency, Fort Monmouth, N. J., recommends a general correlation procedure to be followed by crystal-unit manufacturers. The measuring system is presumed to include the types of equipment indicated in figures 2-92 and 2-93.

2-137. To illustrate each step, let us suppose that we are a manufacturer with the same test facilities as those used at WADC, shown in figure 2-94. Further, let it be supposed that it is planned to test a 12-mc CR-18/U crystal unit over its operating temperature range. Also, assume that the test location is within ground-wave range of Station WWV and that all other necessary standards and accessories are available. With these suppositions, we shall briefly outline the steps to take in following the ASESA recommended correlation procedures.

Correlation of Load-Capacitance Dial

2-138. The calibration of a load-capacitance dial does not require frequent correlation against a standard precision capacitor, but the check is necessary when a CI meter is first installed and whenever precise values of load capacitance are required.

a. If the CI meter is to be used for a wide variety of measurements, it would be advantageous to

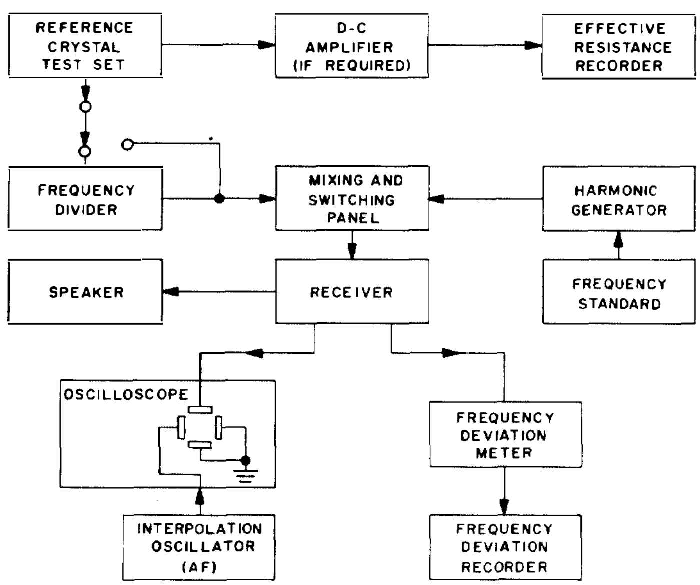


Figure 2-93. System recommended for Government inspection measurements of crystal frequencies over the operating temperature range. The instantaneous frequency-measuring system is the same as that shown in figure 2-80 for room temperature measurements. Added are the frequency-deviation recorder circuit and the effective-resistance recorder circuit

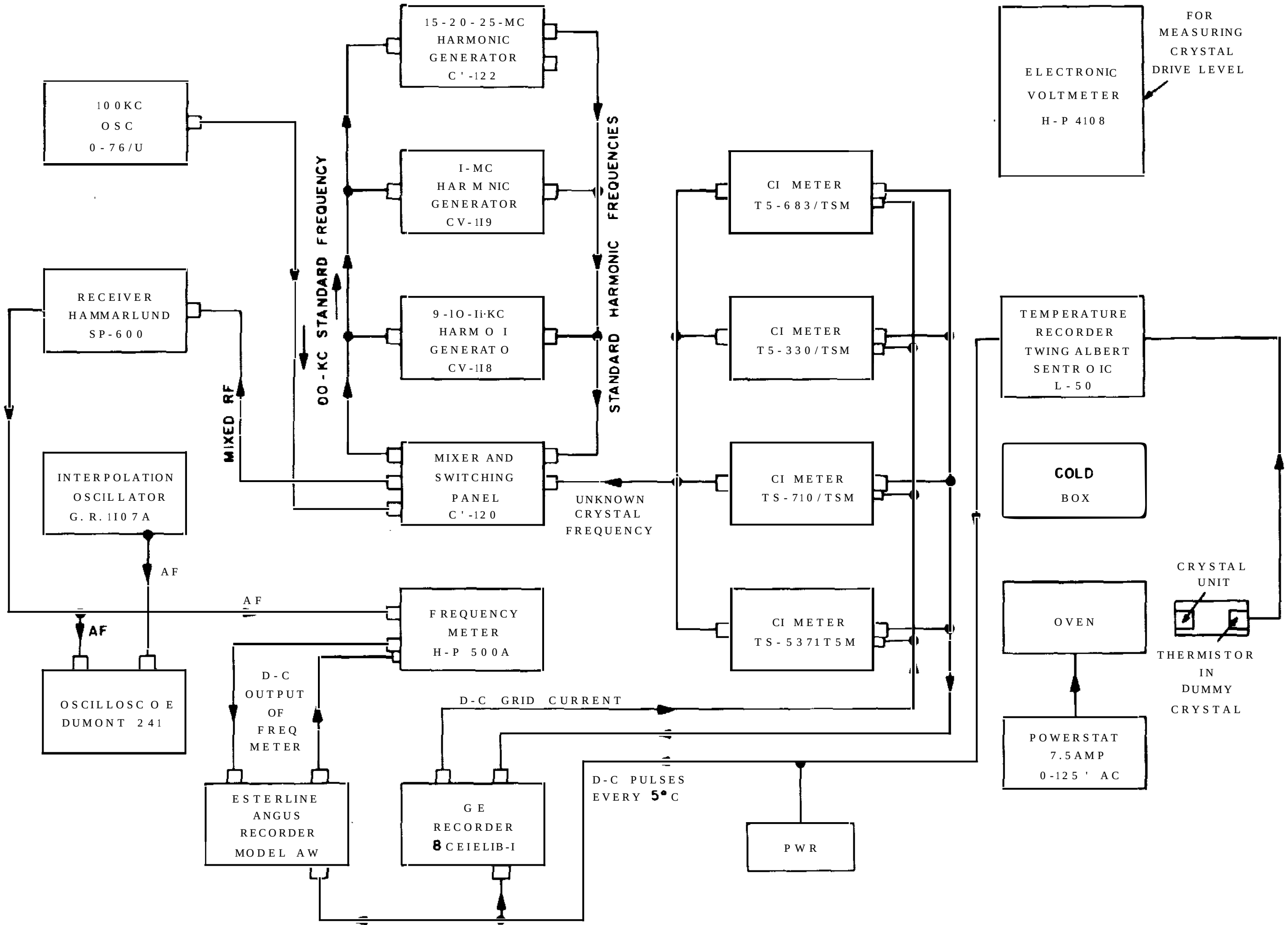


Figure 2-94. System and equipment used at Wright Air Development Center to perform tests on preproduction crystal units

prepare a graphical chart in which the dial settings are plotted against capacitance over the entire adjustable range. If the CI meter is to be used only in measurements of crystal units which, for parallel-mode operation, require no more than one or two standard values of load capacitance, the capacitance dial need be correlated only at the one or two operating positions.

b. For the 12-mc CR-18/U crystal unit we have chosen as an example, the standard reference test set is CI Meter TS-330/TSM. The reference test load capacitance is specified to be 32 $\mu\mu$f. Let it be assumed that the load-capacitance dials of both the primary standard and the reference test sets are to be calibrated at this one position. The procedure to use is the same for each set.

c. Two procedures are possible. If the precision capacitor being used as a primary standard has a value equal to 32 $\mu\mu$f, the correlation can proceed by direct substitution. If the precision capacitor is variable, but all capacitance values are greater than 32 $\mu\mu$f, the correlation depends upon matching the test-set load capacitance with a 32-$\mu\mu$f *difference* between two values of the capacitance standard. The latter method is generally the more accurate, and also faster if a variable capacitor is to be calibrated over its entire range.

d. Direct-Substitution Method. Connect the standard 32-$\mu\mu$f capacitor, with leads as short as possible, across the crystal socket in the test set. With the test set tuned to the lowest frequency band and switched to series-resonance operation (internal load capacitor shorted out), turn the set on and, after warm up, check the operating frequency by mixing with crystal-controlled 10-kc harmonics and detecting the audio beat in the receiver speaker. Adjust the tuning capacitor (not the precision capacitor) of the test set until a zero beat is obtained. Remove the precision capacitor and connect a shorting wire across the crystal socket of the test set. Switch the test set to parallel-resonance operation (load capacitor connected into circuit) and adjust the load capacitor until a zero beat is obtained with the same 10-kc harmonic as before. The dial reading of the load capacitor, when adjusted from a clockwise direction, can be recorded as the 32-$\mu\mu$f position. Note that once the test-set *tuning* capacitor has been adjusted to a zero beat with the standard capacitor connected in the circuit, its adjustment is not changed while the load capacitor is connected in the circuit. The above test should permit an operating accuracy for the load capacitance within 0.2 or 0.3 $\mu\mu$f, provided the standard capacitor is, itself, accurate to within 0.1 $\mu\mu$f. If a more accurate measurement is desired, a Q meter should be employed in a manner similar to the test illustrated in figure 2-95, except that in using a 32-$\mu\mu$f standard, the capacitors are connected in the Q-meter circuit one at a time, rather than in parallel.

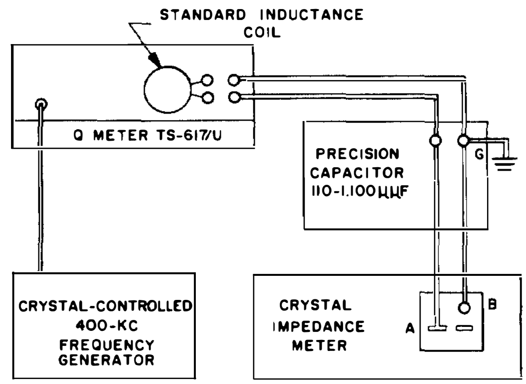


Figure 2-95. Constant parallel-capacitance method for calibration of load capacitance dial

e. Constant Parallel-Capacitance Method. When the lowest value of the precision capacitor is greater than the capacitance to be calibrated, as would be the case if using the G.R. 722-D precision capacitor, a Q meter and a crystal-controlled 400-kc frequency generator can be employed in the manner shown in figure 2-95. Use AWG #12 solid copper wire, supported on 2-inch centers, in connecting the capacitors to the Q meter, keeping leads as short as possible. Lead A connects to the side of the crystal socket making direct electrical contact to one plate of the load capacitor. Lead B connects to the other side of the load capacitor. (Electrical connection to the other plate of the load capacitor can normally be made through one of the rivets that holds the crystal socket in place.) Adjust the precision capacitor to 200 $\mu\mu$f. At the beginning of the test, all leads should be connected except lead A. However, lead A should have the same physical relationship with lead B and with ground as will exist when the load capacitor is connected in the circuit. With the frequency generator driving the circuit, the standard inductance is tuned to resonance with the 200-$\mu\mu$f standard capacitance (plus the distributed wiring capacitance), as indicated by the Q meter. With the standard inductance kept constant, the precision capacitance can be reduced 32 $\mu\mu$f to 168 $\mu\mu$f. Then by connecting lead A, the test-set load capacitor is connected in parallel with the precision capacitor. By adjusting the load-capacitor dial until the Q meter again indicates resonance, it can be assumed that the 32 $\mu\mu$f subtracted from the circuit has now been restored. Record the load-capacitor dial setting, reached with a clockwise rotation, as the 32-$\mu\mu$f position. The foregoing procedure should permit an operating accuracy of plus or minus 0.1 $\mu\mu$f in the value of the test-set load capacitance.

Correlation of Reference Calibrated Resistors

2-139. The reference calibrated resistors, which are used as substitutes for the effective resistance of crystal units when adjusting the drive level and when measuring crystal resistance, do not require frequent checking, but should be measured with a standard r-f bridge before being used for an extensive series of tests.

a. The measured value of the resistor should equal the calibrated value within plus or minus 1 per cent.

b. In testing the 12-mc CR-18/U taken as an example, a calibrated 25-ohm r-f resistor is required to represent the maximum permissible effective resistance. If a standard CI Meter TS-330/TSM is being used in making the test, a set of calibrated decade resistors with appropriate circuit-control switches is included as a component part of the CI-meter circuit design. When measured with an accurate r-f bridge, such as Navy Type No. 69904, the observed value should lie between 24.75 and 25.25 ohms.

Correlation of Reference Crystal Test Set

2-140. Correlation of a manufacturer's reference test set with the Government standard set is performed by, or under the surveillance of, a Government inspector.

a. At least three crystal units of the type to be tested are selected.

b. The frequency and effective resistance of each crystal unit are measured and recorded under standard test conditions when the crystal unit is connected in the primary test set standard. The same measurements are repeated and recorded with the crystal unit connected in the reference test set.

c. The frequency correlation is satisfactory if the frequency of each crystal unit, as measured in the standard test set, does not differ from the frequency of the same crystal unit, as measured in the reference set, by more than plus or minus 10 per cent of the nominal frequency *tolerance.* (For the 12-mc CR-18/U, the specified nominal frequency tolerance is plus or minus 0.005 per cent of 12 mc, which is equal to plus or minus 600 cps. 10 per cent of 600 cps requires that the frequency of each 12-mc CR-18/U unit, as measured with the reference test set, must not differ by more than plus or minus 60 cps from the frequency of the same unit when measured with the primary standard test set.)

d. The effective-resistance correlation is satisfactory if the effective resistance of each crystal unit, as measured in the standard test set, does not differ from the effective resistance of the same crystal unit, as measured in the reference test set, by more than plus or minus 5 per cent of the standard-test-set measured value. (For example, suppose the effective-resistance value of the CR-18/U crystal unit, as measured with the primary standard test set, is 10 ohms. The measurement of the resistance of the same crystal unit in the reference test set must lie between 9.5 and 10.5 ohms, if the correlation is to be assumed satisfactory.)

e. In the event that correlation cannot be achieved, the bureau or service concerned is to be notified.

Correlation of Secondary Frequency Standard

2-141. The secondary standard must be checked against the primary before each series of measurements, and at least three times during any day following a warm-up period.

a. Turn on the standard (O-76/U in our example) and allow to warm up for at least one hour. If the equipment is to be used regularly, the frequency standard should be kept in continuous operation throughout its lifetime.

b. Tune radio receiver to highest usable groundwave frequency from Station WWV (25, 20, 15, 10, 5, or 2.5 mc), and adjust tuning dial for maximum carrier level.

c. Feed output from standard to receiver antenna input, with receiver adjusted for mcw operation, and audio output applied to speaker.

d. Adjust fine frequency control on standard to center of zero-beat region as heard in speaker during 30-second C-W broadcast intervals of WWV. (If it is possible to detect the zero beat directly by the waxing and waning of interpolation-oscillator noise, the correlation period is not limited to the 30-second C-W intervals. If the noise modulation is not audible and greater accuracy is desired, let interpolation oscillator warm up, then set at a very, very low frequency. Feed output of oscillator to horizontal deflection plates of oscilloscope, and output of receiver to vertical plates. Adjust fine tuning of standard to obtain a stationary elliptical pattern on oscilloscope on both sides of zero beat. Zero beat should coincide with fine tuning point of standard exactly midway between points of stationary patterns.)

Correlation of Interpolation Oscillator

2-142. The interpolation oscillator should be correlated at the beginning of each series of experiments after permitting at least one-half hour warm up.

a. Switch on 10-kc harmonic generator under control of 100-kc standard.

b. Switch receiver to lowest frequency band, mcw operation.

c. Adjust receiver selectivity to maximum bandwidth reception.

d. Tune receiver to any frequency midway between two adjacent 10-kc harmonics.

e. Feed audio difference frequency, 10 kc, of the two received signals to vertical plates of oscilloscope.

f. After warm up, adjust interpolation-oscillator tuning dial to 5000 cps, and feed output to horizontal deflection plates of oscilloscope.

g. Adjust calibration controls of interpolation oscillator according to instruction manual until a stationary lissajous pattern is obtained on oscilloscope screen. The pattern should indicate two vertical cycles for each horizontal cycle. With the deflection voltages properly phased, this "two-to-one" pattern will resemble a horizontal figure 8.

h. With the position of the calibration control recorded, the interpolation oscillator will be calibrated for 5000 cps.

i. If the interpolation oscillator is tuned to 3333 cps and adjusted for a stationary "three-to-one" pattern, a calibrated check point at this frequency can be recorded. Similarly, stationary patterns in any ratio from 4:1 to 20:1 can provide calibrated check points at the respective frequencies between 2500 cps and 500 cps. At frequencies below 500 cps, the calibration points can be obtained by correlation with the 60-cps line voltage. Federal regulations require that a commercial 60-cps power frequency be accurate within $\pm$ ½ cps. Since the 60-cps reference can be readily obtained by adjustment of the appropriate oscilloscope control, this calibrating method is quite convenient where great accuracy is not essential. Otherwise, the low a-f check points should be obtained by using as standards the 440-cps and 600-cps signals of Station WWV—ground- or sky-wave r-f reception.

j. When using the interpolation oscillator to correlate the frequency-deviation meter, maximum accuracy is ensured if the interpolation oscillator is specifically correlated at the harmonic check point nearest the frequency corresponding to the maximum nominal frequency tolerance of the crystal unit to be tested.

k. In the case of the 12-mc CR-18/U crystal unit, a crystal of exactly the right operating frequency will produce a zero beat when matched against the nearest harmonic of the frequency standard—assuming the test standards as shown in figure 2-82 are available. With a nominal frequency tolerance of plus or minus 600 cps at any temperature in the operating range, a crystal unit at the edge of the tolerance limit will produce a 600-cps receiver output to be fed to the deviation-frequency meter. The two nearest 10-kc check points for the interpolation oscillator are the 16:1 pattern at 625 cps and the 17:1 pattern at 588.2 cps. Each of these points should be calibrated. (Normally, if a precision oscillator, such as the General Radio Interpolation Oscillator, is used, special correlation adjustments for each frequency are not necessary.)

l. An alternative method, ensuring even greater accuracy in this particular example, is to calibrate the 600-cps setting directly against the 600-cps modulation standard of Station WWV.

Correlation of Frequency-Deviation Meter and Recorder

2-143. The frequency-deviation meter and recorder should be correlated at the beginning of each series of tests.

a. Tune interpolation oscillator to the frequency corresponding to the maximum permissible tolerance for the crystal unit being tested. (For the 12-mc CR-18/U, this means tuning the interpolation oscillator to 600 cps. The dial setting can be interpolated between the calibrated points of 588.2 and 625 cps. For this particular frequency, the 10th harmonic of 60 cps, we might be tempted to check the dial setting against the 60-cps line voltage for a stationary 10:1 pattern. This can readily be done with the normal oscilloscope front-panel controls. But it should be remembered that since the line frequency of 60 cps is not guaranteed beyond $\pm$ ½ cps, a calibration at 600 cps can result in an error of $\pm$ 5 cps.)

b. Feed output of interpolation oscillator to input of frequency-deviation meter.

c. With frequency-deviation meter and recorder placed in operation, adjust calibration control of meter until meter indicates same reading as interpolation oscillator. (For the facilities and crystal unit taken as an example, the H-P 500A meter will be switched to the 0-to-1-kc band and the calibration control adjusted so that the meter reads 600 cps.)

d. Adjust sensitivity of frequency-deviation recorder to provide approximately full-scale reading for interpolation oscillator frequency. (For the meter d-c output corresponding to a 600-cps input signal, the deflection of the recorder stylus should be adjusted to give a convenient large-amplitude reading calibrated to read 600 cps.)

e. The correlation of the frequency-deviation circuit is completed, so the interpolation-oscillator is disconnected from the frequency meter, and the output circuit of the receiver is connected in its place.

Correlation of Effective-Resistance Recorder

2-144. The stylus of the effective-resistance recorder is to be under the control of the d-c grid current of the reference crystal test set. The grid circuit of the test set must be modified so that the grid current passes through the input circuit of the recorder, or through the input circuit of an intermediary d-c amplifier. The resistance of the input circuit should not increase the total grid-leak resistance by more than 5 per cent. Otherwise, make some compensating change in the original grid resistance. If not already provided by the test set, a grid current meter and a variable resistor in parallel with it should be available to be connected in series with the grid-leak resistance. The variable resistor, normally 0 to 1000 ohms plus or minus 10 per cent, is used to control effectively the sensitivity of the grid meter. Once the grid meter sensitivity has been set, it must not be changed during the remainder of the correlation procedure.

a. If the maximum expected grid current (defined in step i) is insufficient to provide a full-amplitude deflection of the recorder stylus, a d-c amplifier must be inserted to boost the input to the recorder. (To avoid confusion, we shall consider only the recorder input circuit. The correlation procedure is not fundamentally affected if, in practice, a d-c amplifier is employed. The amplifier need only be interpreted as being the input circuit and sensitivity control of the recorder.)

b. If the maximum expected grid current is more than sufficient to provide a full-scale deflection of the recorder arm, the recorder sensitivity control should be adjusted to a lower value. If the sensitivity control is not adjustable to a relatively low level, it can be made so by shunting the recorder input with a suitable variable resistance. Under no circumstances should an attempt be made to match the sensitivity of the recorder by adjustments of the grid current. The grid-leak current is effectively standardized for each value of effective resistance for each Military Standard crystal unit and nominal frequency. This is because a standard reference circuit is employed that is designed with a fixed grid-leak resistance, and it is operated with a standardized drive adjustment. All of which means that an approximately predetermined grid current will flow for a given frequency and effective resistance. An increase in the grid resistance, for example, would mean, that for the same drive adjustment procedure, the grid bias would be greater, and hence the harmonic distortion in the output would increase, with a consequent increase in the instability. (Where the nomenclature used in the instruction manual and on the front panel of a CI meter designates the sensitivity control of the grid-current meter to be a "grid-current control," the reader should not be misled into thinking that an adjustment of the percentage of grid current flowing through the meter has a significant effect upon the total grid current.)

c. It is to be assumed at this point that the grid circuit is properly connected to the recorder control circuit, that the maximum expected grid current is ample to permit a full scale deflection of the stylus, and that the total grid-leak resistance has not been significantly changed by the insertion of the recorder input resistance.

d. Adjust the reference crystal test circuit that is to be used in testing the crystal unit to the proper drive level, as defined by the applicable Military Standard drive adjustment procedure. (For testing the 12-mc CR-18/U in our example, the reference set will be a CI Meter TS-330/TSM, and the appropriate drive adjustment procedure, defined by *Military Specification* MIL-C-3098B, is described in paragraph 2-60 of this Handbook. In step b of the drive adjustment procedure, the correct decade resistor value is 13 ohms, since the 12-mc CR-18/U is used as a non-temperature controlled unit. In steps c and d of the drive adjustment procedure, the correct test frequency and crystal current, respectively, for the sample CR-18/U are 12 mc and 20 ma.)

e. After the drive adjustment is completed, a calibrated reference resistor is selected whose value is equal to the maximum permissible for the particular crystal unit to be tested. This resistor is to be connected in the test circuit to simulate the resonance impedance of a series-mode crystal unit, or that of a parallel-mode crystal unit in series with its load capacitance. In other words, with the resistor substituted in the circuit in place of the crystal unit, or the crystal-unit-load-capacitor combination, and with the resulting LCR circuit tuned to the nominal operating frequency of the crystal unit, the amplitude of oscillation should approximately equal the amplitude that would exist if a crystal unit of maximum effective resistance were connected in the circuit. (For example, the maximum permissible resistance of the 12-mc CR-18/U is 25 ohms. The calibrated resistor of this value will be the decade resistance of the TS-330/TSM test circuit. So to perform this step, we need only switch from the 13-ohm resistor used in the drive adjustment to the 25-ohm resistor. The test set remains in the "calibrate" position.)

f. Tune the test set to the nominal frequency of the crystal unit to be tested. (In our particular example, the test set is assumed to have been tuned to the nominal frequency of 12 mc during the drive adjustment procedure. We now make a more exact tuning adjustment by mixing the output of the CI meter with the output of the standard-controlled 1-mc harmonic generator. When the test set is correctly tuned, a zero beat will be obtained in the receiver speaker resulting from the mixture of the 12th harmonic of the generator with the test-set output.)

g. Adjust the grid-current meter sensitivity to give a convenient low-scale reading. Mark the position of the sensitivity control and record the grid current. This represents the minimum permissible grid current for the type of crystal unit and frequency under test, since it corresponds to the maximum permissible effective resistance.

h. Now adjust the recorder and calibrate the graph for a reading of the maximum effective resistance. When correlating the position of the recorder stylus with the effective-resistance scale of the graph, the position of the stylus when the grid current is minimum must be adjusted to give a reading corresponding to the maximum permissible resistance (25 ohms for our sample CR-18/U).

i. The maximum expected grid current can be approximated by replacing the calibrating resistor used in making the maximum-resistance correlation with one having a value representing the minimum expected effective resistance. (In our CR-18/U example, we can assume a minimum effective resistance of 4 ohms.) The resulting grid current we define as the *maximum expected grid current.* This is not the current indicated in the grid-current meter, unless the meter sensitivity is turned to its maximum position; even then the reading is only approximate. There is no need to measure the maximum expected grid current unless the value is required to determine whether the recorder sensitivity will need boosting or attenuating.

j. With the sensitivity control of the grid meter adjusted to its previously marked position, record the current reading. This reading will serve as the meter indication that the maximum expected grid current is flowing. It is valid only for the given adjustment of the meter sensitivity. With the meter indicating the maximum expected grid current, adjust the sensitivity of the stylus deflection for a full amplitude swing. Make this adjustment and calibrate the corresponding reading on the recorder graph, to signify an effective resistance equal to the minimum expected value (4 ohms for our sample CR-18/U).

k. The grid-current meter readings and calibrating adjustments can be recorded and used to speed similar correlation procedures for future crystal tests.

Correlation of Temperature-Measurement Controls (General)

2-145. The details of the procedure for correlating the different reference devices used to control the crystal temperature measurements can be quite varied. In general, four types of measurements or specified test conditions must be correlated with the temperature standards. The crystal unit must start the temperature run at the correct lower temperature limit. Heat must be supplied at a rate sufficient to permit the proper intervals between temperature readings and at a dependable rate so that the length of a temperature run is predictable within plus or minus 5 per cent. The temperature of the crystal unit must be indicated at all times. And finally, the heater must be shut off at the upper temperature limit at the end of the run. The exact methods used to accomplish the above ends vary considerably, depending upon such factors as whether the measurements are for laboratory or production line; whether the measurements are being made for multiple lots or for just one crystal unit at a time; whether a permanent recording of the measurements are being made and, if so, of what type; whether readings are being indicated continuously or only at intervals; whether exact measurements are being made or whether the tests are of the go, no-go type. Even when similar types of tests are being made, the methods vary from laboratory to laboratory and manufacturer to manufacturer, and even from one location to another in the same organization. In spite of the variety encountered in the methods used in measuring and controlling the temperature, the fundamental correlation procedure is applicable generally and should be observed.

Correlation of Pyrometer

2-146. The pyrometer is to be correlated at least once each month that it is being used.

a. Correlate at 0°C by immersing sensing element (moisture protected) in ice water, the water having been distilled.

b. Correlate at boiling point of distilled water making allowance for elevation above sea level, or, if available, exact barometric pressure at time of test. Care should be taken that position of pyrometer sensing element is not in temperature gradient near heat source, nor at liquid surface.

c. The temperature measurements are not so critical that both the freezing and boiling temperatures of distilled water need to be correlated, but for accurate measurements both correlations should be made.

d. If a thermocouple sensing element is used, true accuracy requires that the temperature of the constant-temperature junction be maintained at a known value throughout all measurements. In other words, it should be thermostatically controlled. Also, the difference in temperature between the two junctions should be as large as practicable. In practice, the temperature of one junction follows the variations in the temperature of the surrounding air; hence, when the temperature of the sensing junction approaches room values, the corresponding indication of the pyrometer is quite unreliable. However, in a temperature-run test the correlation of the recorders is less dependent upon the absolute indications of the pyrometer in the middle of the run, than upon the more accurate indications at the limits of the range, and upon the constancy at which the rate of temperature change can be maintained.

e. If a thermistor sensing element is used, the temperature correlation can be more dependable, provided the pyrometer voltage source is stable.

Correlation of Cold Box Thermometer

2-147. The cold box thermometer should be correlated with the reference pyrometer once each month.

a. Place dummy crystal unit of pyrometer in cold box in a position simulating that of a normal crystal unit. (In our example, the dummy crystal unit should be contained in an HC-6/U holder, in order to approach as nearly as possible the physical characteristics of the CR-18/U crystal unit.)

b. Adjust temperature of cold box to lower limit of specified temperature range of crystal unit to be tested, measuring the temperature with the pyrometer. (For our test CR-18/U, the lower temperature limit is minus 55° C.)

c. With thermometer inserted in cold box with pyrometer, allow one-half hour for box and temperature instruments to reach thermal equilibrium.

d. Record difference between readings of pyrometer and thermometer, for use in correcting thermometer reading in later measurements of cold box limit temperature.

Correlation of Heater

2-148. Correlate the heater as follows:

a. Cool dummy crystal unit in cold box until it reaches thermal equilibrium at specified low temperature limit for crystal unit to be tested. Temperature is to be read by pyrometer with sensing element attached to crystal plate in dummy unit.

b. Mount dummy crystal unit in heater and begin test temperature run. As read on pyrometer with sensing element attached to quartz plate, carefully measure time required for temperature to reach upper limit. Adjust heater thermostat to cut off power as upper limit is reached (90°C in the case of the CR-18/U example).

c. The heater power is adjusted, if necessary, to ensure that the rate of temperature change meets the specified test conditions. (For the CR-18/U unit in our example, the test conditions specified in Method A must be met. See paragraph 2-36a.)

d. If the periods of three consecutive temperature runs, as specified in steps a and b, meeting the specified test conditions without adjustments of the heater controls, are within plus or minus 10 per cent of each other, the correlation is satisfactory.

Correlation of Recorders with Temperature Range

2-149. The correlation of the recorder with the temperature range will depend upon the facilities available and the degree of accuracy desired.

a. If special facilities are not available, the correlation of the graphical recordings of the frequency and effective resistance with the operating temperature are normally made at only the two temperature limits, which can manually be made to coincide with the starting and stopping of the recorders. If desired, manual calibrations can be obtained at a mid-temperature by observing the pyrometer scale.

b. With special test facilities, such as the modified temperature recorder indicated in figure 2-94, temperature calibrating pulses can be transmitted to the graphical recorders at any desired temperature interval. These pulses are correlated with, and adjusted for control by, the dummy crystal unit pyrometer circuit. The temperature recorder indicated in figure 2-94 is modified to provide a temperature-indicator pulse to the frequency and resistance recorders at every 5°C change in temperature of the dummy crystal unit.

Correlation of Vibration Machine

2-150. The vibration machine must be correlated for amplitude and frequency at least once each month. With machine in operation, draw lines to indicate amplitude on marking surface held at right angles to direction of vibration. Check amplitude with inch scale at different frequencies to ensure that Military Specifications are met over vibration range. See paragraph 2-48.

MEASURING AND RECORDING FREQUENCY AND EFFECTIVE RESISTANCE

2-151. Assume that the equipment in figure 2-94 is available and that all correlations have been made prerequisite for measuring and recording the frequency and effective resistance of a 12-mc CR-18/U crystal unit over its operating temperature range.

a. Adjust drive of reference crystal test set TS-330/TSM according to correct drive adjustment procedure as specified in paragraph 2-60.

b. Adjust TS-330/TSM for operation of CR-18/U type unit at 12 mc according to instructions in manufacturer's manual, or in USAF Technical Order No. 35TS330-5, or in Signal Corps Technical Manual No. TM 11-5051.

[Briefly, the load capacitance is set at 32 $\mu\mu$f, but is not immediately connected into the circuit. Insert a sample 12-mc CR-18/U crystal unit in the crystal socket. (A sample is inserted since presumably the unit to be tested is being cooled in the cold box.) With the circuit switched for series-mode operation, adjust the tuning capacitor until resonance is indicated by a grid-current peak. We assume that the grid-current meter sensitivity has been adjusted for a suitable reading. Do not change the drive adjustment (the crystal-current control). The Military Standard drive adjustment procedures can be assumed to supersede possible contrary instructions in operating manuals. Now, switch in the load capacitance, and the circuit is ready for operation.

If desired, since the 12-kc harmonic standard is available to ensure an accurate tuning to the nominal frequency, the circuit could be precisely tuned during the drive adjustment procedure, and the only adjustments necessary would be to disconnect the drive-adjustment resistor from the circuit, switch in the 32-ohm load capacitor, and then insert the crystal unit in its socket when the test is ready to begin.]

c. With sample crystal unit in operation, feed signal from test set through switching panel to receiver input.

d. Feed harmonic output of 1-mc standard-controlled generator to receiver input.

e. Tune receiver, mcw operation, to receive nominal 12-mc signal. Beat note, if fed to speaker, indicates difference between test crystal frequency and 12th harmonic of 1-mc standard-controlled generator.

f. Select range of frequency-deviation meter that corresponds to the maximum permissible frequency deviation for the crystal unit being tested (600 cps in this case, and the proper meter range would be that from 0 to 1000 cps).

g. Feed audio output from receiver to frequency-deviation meter.

h. Feed output of frequency-deviation meter to input of frequency-deviation recorder.

i. Feed grid current from crystal test set to input of effective-resistance recorder.

j. Feed output of temperature recorder to temperature-pulse inputs of frequency-deviation and effective-resistance recorders.

k. From cold box take test crystal unit and dummy crystal unit, both cooled to the low temperature limit and mounted in slug. Insert slug in oven.

l. Insert crystal pins, protruding from oven holder, in crystal socket of test set.

m. Turn on heater power and start temperature run.