16

Integrated Circuit Oscillators

16.1 INTRODUCTION (SEE ALSO SECTION 15.1)

This chapter covers the integrated circuits which are explicitly rated and described for use in oscillators, in contrast to the gate oscillators of Chapter 15. These integrated circuits require only the addition of a crystal and perhaps some capacitors and overtone/mode selector to make up a complete *oscillator* which provides a rated output into a rated load. Sometimes the complete *oscillator* is included within the chip enclosure. Sometimes the oscillator function is only part of the total chip functions which may include dividers, phase detectors, and so on, but in that case specific information is given for the oscillator function.

The information available for using these chips ranges from extremely poor to extremely good. The performance of the chips tends to improve as the quality of the information improves. The minimum information supplied are the pin connections, power supply requirements, and the recommended operating frequency range. The latter information is insufficient to produce a satisfactory oscillator design. The minimum required, in addition, are descriptions of the recommended crystal characteristics, the total oscillator performance with these crystals as a function of power supply, and environmental conditions, assuming the crystal performance to be independent of environmental conditions.

Because of the large number of circuits introduced and/or available, a detailed treatment of all the circuits is impractical. A number of general principles and comments are stated, which should be helpful in the design and application of the circuits. Examples of some popular readily available circuits are given and references are cited which discuss their measured performance, which is often at variance with the circuit manufacturer's specifications. In view of the large discrepancies that often exist between the measured and

specification performances, it is highly recommended that each lot of circuits be carefully screened to ensure performance adequate for the application.

The chapter discusses the following types of oscillators:

1. Gate oscillators not considered in Chapter 15.
2. Linear integrated circuit oscillators.
3. Miniature oscillators which include the crystal in the same package that contains the circuitry. The circuitry may be gate type, linear integrated circuit type, and/or hybrid types only, which may be composed solely of thick-film discrete elements or discrete components combined with integrated circuits.

16.2 GATE OSCILLATORS WITH DIGITAL OUTPUT

The operating principles of this class of oscillator is covered in Chapter 15. Several examples of commercially available oscillators (in the year 1981) are now discussed.

16.2.1 Clock Oscillator 8224 of the 8080 Microprocessor System

This oscillator normally operates at 4 MHz. The circuit is the series resonant type. Extensive tests were made at various frequencies and are reported by Holmbeck in Ref. 15.2. Curves of L_{eq} versus f from 4 to 12 MHz are included. L_{eq} is shown to increase as f increases. However, these curves do not state the crystal current or the characteristics of the crystals used for obtaining the data. Repeatability between different units is reported as being poor, particularly at the higher frequencies.

16.2.2 The 74124 and 74324 and Their Schottky and Low-Power Schottky Version Oscillators

These are basically voltage-controlled oscillators. When a crystal is provided instead of the frequency-determining capacitor, the oscillator is intended to operate as a crystal-controlled oscillator. As VCOs, they are rated for operation from several Hz to 30 MHz. As crystal oscillators, they will operate up to 20 MHz, depending upon the gates or chips, but up to several thousand ppm below the crystal frequency. No data is given for the required crystal characteristics.

Reference 15.2 includes curves of L_{eq} versus f from 10 to 20 MHz for the Schottky version. The repeatability between units also is reported to be poor.

In general these circuits do not appear very attractive for crystal oscillator use.

16.2.3 The Plessy SP 705 Oscillator

This is a series resonant crystal oscillator provided with $\div 2$ and $\div 4$ output circuits. These units are rated to operate from 1 to 10 MHz. The oscillator is discussed in Ref. 13.7 and is reported to be unreliable.

16.2.4 "Wristwatch" Oscillators

These oscillators are examples of the successful application of gates to oscillators. The oscillators use the antiresonant circuits of Fig. 15.7 and require two capacitors. One of the capacitors may be contained within the chip. The remaining capacitors and the crystal are external to the chip. The oscilllators operate in the frequency range from 30 kHz to 1 MHz and possess moderate and adequately repeatable performance. The descriptive data includes information on the required crystal characteristics.

The oscillators form part of the complete chip which also includes dividers, drivers, and so on. The chips generally are CMOS to conserve power, which increases as the oscillator frequency increases.

Examples of these "wristwatch" chips are as follows:

1 Motorola MC 14450 Oscillator/2^{16} Divider/Buffer for a 32-kHz crystal.
2 Motorola MC14451 Oscillator/2^{11} to 2^{19} Divider/Buffered Duty Cycle Control for 30 kHz to 1 MHz.

16.3 LINEAR INTEGRATED CIRCUIT OSCILLATORS

The operating principles of these oscillators are covered in Chapters 5 to 13. The oscillators may consist of

1 Discrete passive and active components combined with integrated circuit active elements. The design is identical and the performance is equal to or only slightly inferior to the oscillators described in those chapters. Reference 16.1 describes the application of some general purpose linear integrated circuits to oscillator design.

2 Integrated circuit chips which require only the addition of some capacitor and/or overtone/mode selector to make up a complete *oscillator* which provides a rated output into a rated load. The output signal may be sine wave or digital. Also, the oscillator may be part of a chip containing a system. Meyer and Soo present, in Ref. 16.8, excellent detailed treatments of the design of this

type of oscillator, using NMOS active elements and the NMOS large-signal characteristics.

Oscillators of the first type have already been completely described in the previous chapters. Several examples of commercially available oscillators of the second type are now discussed.

16.3.1 National DS 8907 Digital Phase-Locked Loop Frequency Synthesizer

This chip contains the greater part of the frequency synthesizer for FM/AM receivers. The internal Colpitts oscillator operates at 4 MHz. The crystal and the oscillator capacitors are external to the chip. The performance is moderate and repeatable. Many of these chips are in successful use.

16.3.2 The MC-12060, MC 12560, 12061, and the 12561 Oscillator Groups

These are chips which only require an external crystal and bypass capacitors to produce a complete *oscillator*. The outputs are sine wave, TTL, and ECL. The −60 series is intended for frequency ranges of 100 kHz to 2 MHz, and the −61 series for 2 to 20 MHz. The data sheets include considerable information, including performance and crystal requirements.

The oscillator circuit is a modification of the series resonant circuit described in Section 13.5.4, but is provided with ALC. The performance of these oscillators is discussed in Refs. 13.7, 15.2, and 16.2, wherein they are reported as being better than most IC oscillators but not in compliance with the ratings. Also, considerable care must be taken in their application.

16.3.3 The Plessy SL 680A Oscillators

This unit is rated to operate from 100 kHz to 100 MHz. The crystal operates near series resonance. The circuit includes ALC and is unique in that it maintains the crystal current constant at about 0.2 mA. The output is sine wave. The performance of this oscillator is discussed in Ref. 13.7 wherein it is reported that the unit operated reliably at the fundamental overtone, up to about 18 MHz, but at frequencies considerably lower than the crystal f_s.

Reference 16.3 describes another application of this unit in a 10-MHz temperature-controlled *oscillator*.

16.4 MINIATURE PACKAGED CRYSTAL *OSCILLATORS*

For many years considerable effort has been expended toward the development of miniature packaged oscillators in which the crystal is within the *oscillator* enclosure. This section presents a sampling of the *oscillators* which have resulted from these efforts.

16.4.1 Microminiature *Oscillator* in TO-5 Enclosure

Reference 16.4, which was published 16 years ago, reports some early efforts in microminiaturization. The *oscillator* operated at 10 MHz used the Colpitts circuit and had moderate performance.

The paper contains a general discussion of the relative merits of monolithic, compatible, and hybrid integrated circuitry. The *oscillator* described used hybrid circuitry. The crystal was unpackaged and used the same TO-5 enclosure for hermetic sealing.

16.4.2 Tactical Miniature Crystal Oscillator

Reference 16.5 describes a high-performance ovenized 5.115-MHz miniature *oscillator*. It uses hybrid circuitry and the crystal is sealed in a flat pack ceramic enclosure adding little to the overall crystal size. The oscillator uses the Colpitts circuit with ALC.

The paper includes much valuable information on component performance and techniques for setting the oscillator frequency to the rated frequency at the crystal temperature turnover point.

16.4.3 Miniature Packaged Crystal *Oscillators* of Ref. 16.6

Reference 16.6 describes a series of miniature *oscillators* for the frequency range of 0.5 to 22 MHz. The performance is moderate, being ± 100 ppm over a temperature range of -40 to 95°C. The output is TTL. The oscillators having outputs below 8 MHz use crystals in the 8 to 22-MHz region combined with frequency dividers. The crystals operate near series resonance.

The circuitry is hybrid, which includes a monolithic silicon integrated circuit. The *oscillators* are housed in TO-8, TO-5, and DIP enclosures, which also provide the crystal hermetic sealing.

The paper is excellent for describing the present state of development of miniature *oscillators*. It also includes much information on the theoretical and practical aspects of oscillator and TTL output circuit design.

16.4.4 Military Specification Miniature *Oscillators*

Reference 16.7 describes a series of miniature *oscillators*, covering the wide frequency range of 1 kHz to 50 MHz. The lower frequencies are obtained by means of frequency dividers. The *oscillators* are housed in a hermetically sealed DIP can. The output is TTL. The rated performance is moderate, being

1. Initial accuracy— $\pm$ 15 ppm at 25°C.
2. Frequency stability versus temperature— $\pm$ 25 ppm from 0 to 70°C; ± 50 ppm from -55 to 125°C.
3. Frequency stability versus supply voltage— $\pm$ 5 ppm for a 0.25-V change in supply voltage which is nominally 5 V.