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## List of Frequently Used Symbols\*

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Symbol	Definition	Page of First Appearance
$A_L$	Oscillator loop gain	16
$A_{L_0}$	Small signal oscillator loop gain	16
$B$	Susceptance in $\mathfrak{U}$ , imaginary component of $Y$	3
$BV_{CE}$	Breakdown voltage between transistor terminals c and e in mV	187
$C$	Capacitance in pF	5
$C_b$	Series capacitor in mode selection networks	156
$C_b$	Base bypass capacitor	251
$C_{bed}$	$C_{b'ed}$ for $r_{bb'} = 0$	48
$C_{bed_0}$	Small signal $C_{bed}$	48
$C_{b'ed}$	Bipolar transistor base emitter diffusion capacitance	38
$C_{b'ed_0}$	Small signal $C_{b'ed}$	38
$C_{bet}$	$C_{b'et}$ for $r_{bb'} = 0$	53
$C_{b'et}$	Bipolar transistor base emitter transition capacitance	39
$C_{cem}$	Transistor collector emitter Miller effect contribution	236
$C_L$	Rated crystal load capacitance	70
$C'_L$	Load matching capacitor	191
$C_L$	Stabilizing capacitor	165
$C_{L_{df}}$	Crystal load capacitance at $f_L + df$	77
$C_M$	Miller effect contribution to $(X_1 + X_2)$	235
$C_N$	Total capacitance in overtone selection network	154
$C_n$	$X_n/(2\pi f)$ $n = 1, 2, \text{etc.}$	191
$C'_N$	Installed part of $C_N$	139
$C'_n$	Installed part of $C_n$ ( $n = 1, 2, \text{etc.}$ )	182
$C_{r_2}$	$r_2$ bypass capacitor	182

\*Unless otherwise stated, the units are those given for the applicable first or second symbol of each letter.

Symbol	Definition	Page of First Appearance
$C_0$	Crystal static capacitance	70
$C'_0$	Crystal static capacitance including external strays	71
$C_1$	Crystal motional capacitance	70
$C_{1M}$	Miller effect contribution to $C_1$	149
$C_{2M}$	Miller effect contribution to $C_2$	149
$df$	Frequency offset from $f_L$ in Hz	71
$F$	Function of	371
$f$	Operating frequency in MHz	5
$\mathbf{f}$	Fourier frequency in Hz	376
$f_L$	Crystal rated frequency with $C_L$	71
$f_N$	Crystal overtone frequency	153
$f_s$	Antiresonant frequency of mode/overtone networks	153
$f_T$	Transistor gain bandwidth product	38
$G$	Conductance in $\mathfrak{G}$ , real component of $Y$	3
$g_m$	Transistor transconductance	48
$g_{me}$	Equivalent $g_m$	210
$g_{mL}$	Transistor limiting $g_m$	174
$g_{mL_0}$	Small signal $g_{mL}$	174
$g_{m_0}$	Small signal $g_m$	28
$h_{FE}$	Low frequency $h_{fe} \equiv \beta_0$	28
$h_{mn}$	$h$ parameter	9
$I$	Current in mA dc or rms*	7
$i$	Instantaneous current in mA	29
$I_A$	dc current in terminal a	47
$i_A$	Total instantaneous current in terminal a	29
$I_a$	ac current in terminal a	146
$I_{aM}$	Current component at frequency $Mf$ in terminal a	47
$I_{a1}$	Fundamental current in terminal a	47
$I_{BB}$	Power supply dc current	196
$I_x$	Crystal current	78
$I_2$	ac current in path or terminal 2	7
$L$	Inductance in $\mu\text{H}$	70
$L_b$	Series inductor in mode selection network	156
$L_N$	Parallel inductor in selection network	154
$L_0$	Crystal $C_0$ neutralizing inductor	251
$L_1$	Crystal motional inductance	70
$M$	Multiplication order	47
$M_{cb}$	$1 + V_{L1}/V_b$	235
$M_{ce}$	$1 + V_{L1}/V_e$	235
$M_M$	$V_{be'}/V_L$	149
$M_M$	$V_{be}/V_e$	235
$m_r$	$R_s/R_L$	211
$N$	Crystal overtone number	82

\*Note the use of upper and lower-case symbols and upper and lower-case subscripts to denote the type of current and the terminal or path.

Symbol	Definition	Page of First Appearance
$n$	$X_2/R_i$	212
$P$	Power in mW	1
$P_A$	Power dissipated in $Z_A$	257
$P_i$	Input power	2
$P_L$	Load power	185
$P_o$	Output power	2
$P_T$	Total power	257
$P_x$	Crystal drive power	78
$Q$	Quality factor	78
$Q_{op}$	Operating $Q$	150
$Q_x$	Crystal $Q$	78
$R$	Resistance in $\Omega$ usually connected in series, real component of $Z$	3
$r$	Resistance in $\Omega$ , usually connected in parallel	38
$r$	Capacitance ratio, $C_0/C_1$	82
$R_A$	Resistance component of $Z_A$	253
$R_b$	Equivalent bias circuit series resistance	144
$r_b$	Thévenin source resistance of the bias circuit	57
$r_{bb'}$	Base spreading resistance	39
$r_{b1}$	Bias resistor between base and $-V_{BB}$	57
$r_{b2}$	Bias resistor between base and $V_{BB}$	57
$R_{df}$	$R_e$ at $f_L + df$	77
$R_E$	Unbypassed emitter resistor	139
$R_e$	Crystal equivalent series resistance	72
$r_e$	Intrinsic emitter dynamic resistance	38
$r'_e$	Extrinsic emitter dynamic resistance	39
$r_{e0}$	Small signal $r_e$	38
$R_{IN}$	Emitter input resistance of the common base transistor	55
$R_{in}$	Equivalent base emitter series resistance	142
$R_{IN_0}$	Small signal value of $R_{IN}$	259
$R_L$	Crystal resistance at $f_L$	71
$R_L$	Tuned load resistance	139
$R_{L_1}$	Fundamental component of $R_L$	238
$r_{mn}$	Resistance between terminals $m$ and $n$	38
$R_N$	Negative resistance	254
$R_n$	Crystal $PI$ -network resistance	209
$r_{osc}$	$V_f/I_X$	371
$r_{par}$	Resistor for suppressing parasitic oscillations	361
$R_s$	Isolating resistor resistance	208
$R_T$	Total equivalent series resistance	144
$R_t$	$R_3 + R_{in}$	212
$R_x$	Same as $R_{df}$	253
$R_1$	Crystal motional resistance	70
$R_2$	Equivalent $Z_2$ series resistance	142
$r_2$	Emitter bias resistor	57
$r_{2\ ac}$	ac value of $r_2$	239

Symbol	Definition	Page of First Appearance
$R_3$	Resonator resistance	144
$s$	$s$ parameter	25
$s$	$f_s/f_N$	153
$S_\phi(f)$	phase spectrum in dbc/Hz	376
$S_{\phi_s}(f)$	phase noise of the circuitry	376
$S_{\phi_{V_f}}(f)$	phase spectrum of the output signal $V_{f_n}$	376
$V$	Voltage in mV dc or rms*	55
$v$	Instantaneous voltage in mV	55
$V_A$	dc voltage between terminal a and the datum (ground)	57
$v_A$	Total instantaneous voltage between terminal a and the datum (ground)	173
$V_a$	ac voltage between terminal a and the datum (ground)	63
$V_{AB}$	dc voltage between terminals a and b	48
$v_{AB}$	Total instantaneous voltage between terminals a and b	48
$V_{ab}$	ac voltage between terminals a and b	48
$V_{BB}$	Power supply voltage	57
$V_L$	ac voltage across the load $R_L$	139
$V_{L_1}$	Fundamental component of $V_L$	235
$X$	Reactance in $\Omega$ , imaginary component of $Z$ , usually connected in series	3
$X_A$	Reactance component of $Z_A$	253
$X_e$	Crystal equivalent series reactance	72
$X_L$	Combined reactance of $L_3$ and $C_V$	255
$X_{L+}$	$X_L$ at which $X_A$ is maximum	269
$X_{L-}$	$X_L$ at which $X_A$ is minimum	270
$X_N$	Negative reactance	254
$X_x$	Crystal reactance at $f_L + df$	253
$X_2$	Total reactance of network 2	141
$X'_2$	Installed reactance of network 2	140
$Y$	Admittance in $\mathcal{U} = G + jB$	3
$Y_A$	Two-port network described by $y$ parameters	9
$Y_A$	Effective Pierce oscillator active circuitry	375
$y_{mn}$	$y$ parameter	8
$Z$	Impedance in $\Omega = R + jX$ , usually connected in series	3
$Z_A$	$Z_x + Z_{IN}$	253
$Z_a$	Two-port network described by $z$ parameters	10
$Z_c$	Impedance seen by the collector	252
$Z_{IN}$	Emitter input impedance	252
$Z_{LL}$	Llator impedance	144
$z_{m_n}$	$z$ parameter	8
$Z_s$	$Z_1 + Z_2 + Z_3$	253

\*Note the use of upper and lower-case symbols and upper and lower-case subscripts to denote the type of voltage and the terminals.

Symbol	Definition	Page of First Appearance
$Z_1$	Oscillator series impedance contributing to the negative resistance	129
$Z_2$	Oscillator series impedance contributing to the negative resistance	129
$Z_3$	Resonator impedance	129
$Z_3$	Impedance of $R_L$ and $X_L$	251
$\alpha$	$h_{fb}$	28
$\alpha$	$g_m/g_{m_0}$	48
$\beta$	$h_{fe}$	28
$\beta_o$	Low frequency $\beta = h_{FE}$	28
$\gamma_M$	$I_{eM}/I_E$ ( $M = 1, 2, 3$ )	48
$\gamma_p$	$i_{peak}/I_E$	48
$\gamma$	$\sqrt{2} I_e/I_E$	56
$\Delta f$	Frequency shift from series resonance	74
$\Delta f$	Change in frequency	75
$\Delta f/f$	Fractional frequency stability	404
$\Delta y$	$y$ determinant	24
$\eta$	Load power divided by the resonator power	185
$\theta$	Phase angle of an immittance	3
$\omega$	Angular frequency = $2\pi f$	73