History of Quartz Crystal

In the early writings of the Roman Empire, quartz crystals are mentioned as mysterious clear rocks throught to be "ice fossils" found in the high alps. However, these colorless, transparent crystals are formed by nature from silicon and oxygen under high pressure and temperature.

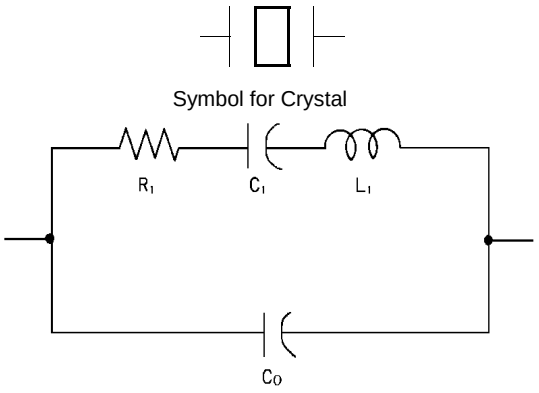
The Piezoelectric effect was discovered in the early 1880's by Pierre and Jacques Currie that when pressure applied to a quartz crystal generated voltage; and that voltage applied across a crystal produced mechanical motion or vibration.

Because of the scarcity of natural quartz, a process was developed using autoclaves for growing cultured quartz of high quality and reliability. The exceptional purity of and quality of cultured quartz crystal create virtually limitless possibilities for crystal applied products in the ever growing electronics markets.

Quartz Crystal Terms and Definitions

The frequency characteristics of crystal are dependent on the following factors and must be considered when specifying a quartz crystal. The (REF 2.0, 3.2, etc.) refers to the technical data for quartz crystal on the following pages. These definitions are also useful for the SMD quartz crystal and Tubular quartz crystal sections.

EQUIVALENT CIRCUIT



Symbol for Crystal

Equivalent circuit

The circuit, as illustrated, denotes the quantities L_1 , C_1, R_1 and C_0 as the electrical equivalent of the electromechanical and electrical properties of the quartz and holder assembly, L_1 and C_1 are referred to as the motional inductance and capacitance respectively, and R_1 is known as the series resistance.

C_0 is the static or shunt capacitance whose value is the sum of the capacitance between the electrodes and capacitance added by the leads and holder.

FREQUENCY STABILITY (REF 2.0)

The amount of frequency deviation from the ambient temperature frequency. This deviation is associated with a set of operating conditions including: Operating Temperature Range, Load Capacitance, and Drive Level. This parameter is specified with a maximum and minimum frequency deviation, expressed in percent (%) or parts per million (PPM). The frequency stability is determined by the following factors: Type of quartz cut, angle of the quartz cut, mode of oscillation, and mechanical dimension of the quartz

FREQUENCY CALIBRATION TOLERANCE (REF 3.2)

The amount of frequency deviation from a specified center frequency at ambient temperature (referenced at 25°C). This parameter is specified with a maximum and minimum frequency deviation, expressed in percent (%) or parts per million (PPM).

PULLABILITY (REF 3.3)

(used mostly in “communications” applications) - is defined as the change of frequency as a function of change in load capacitance. The load capacitance is either in series or in parallel with the crystal.

For example, a 10 MHz fundamental crystal with a C_1 of 22 ff and a Co of 5 pf, in a circuit load capacitance of 30 pf, would increase in frequency by 8 ppm if the load was adjusted to 29 pf.

$$\text{Pullability (ppm/pf)} = \frac{(C_1)(10^6)}{2(Co + C_L)^2}$$

C_1 - Motional Cap.

C_L - Load Cap. of Circuit

Co - Crystal Shunt Cap. Fund.

* All capacities for formula in pf

	Freq (MHz)	C_1 (ff)	Co (pf)
	1.0-2.0	5-8	3
	2.0-4.0	6-12	3
	4.0-6.5	8-20	5
	6.5-25	16-25	6
3rd OT	20-75	1.0-2.5	6
5th OT	50-125	<.7	6
7th OT	100-175	<.4	6

Quartz Crystal Terms and Definitions

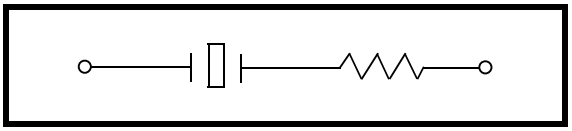
C_L - LOAD CAPACITANCE (REF 3.4)

The circuit condition the crystal will be operated in. Where the circuit design presents a capacitance to the crystal the frequency is raised above series resonance (F_S) related to the capacitance. The Load Capacitance is the combination of components and strays that will determine crystal reactance and therefore its frequency. Specifying C_L is either done by stating "series" (no crystal reactance) or by specifying a number such as 20, 30, 50, etc.

SERIES RESONANCE (REF 3.4)

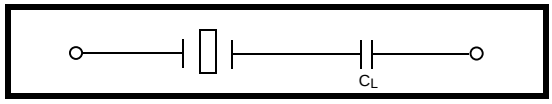
It is simple to measure or correlate frequency in crystals operating at series resonance. Series resonance appears resistive in the circuit and impedance at f_S is at its minimum value. Unless load capacitance is specified, all crystals are manufactured at series resonance.

Series Resonance



PARALLEL RESONANCE (REF 3.4)

When a crystal is operating at parallel resonance (f_L) it will look inductive in a circuit. Crystal frequency varies depending on the value of load capacitance (C_L). The load capacitance is the dynamic capacitance of the total circuit as measured or computed across the crystal terminals. Frequency increases as load capacitance decreases. In parallel circuit designs, the load capacitance should be selected to operate the crystal at a stable point on the f_S-f_a (anti-resonance) curve, as close to fs as possible. Always specify the load capacitance if the crystal will be operated in the parallel mode. Typical values are 20pf, 30pf and 32pf.



EFFECTIVE SERIES RESISTANCE (REF 3.5)

This is the value, in OHMS, which is the equivalent resistance of the crystal when operated in series resonance. It is used as a measure of the quality of the crystal, since the lower the resistance, the easier for the circuit to operate. The resistance of the crystal is controlled by the manufacturing process.

DRIVE LEVEL (REF 3.6)

Power dissipated through a crystal in an operating circuit is expressed as the drive level. A drive level (measured in microwatts) which is too high or too low can cause undesirable effects. Drive levels vary from tenths of a milliwatt for low frequency crystals to 10µW for high frequency crystals. If the level is too high, it can cause the oscillator frequency to change, cause a fracture in the quartz element or lead to a permanent shift in frequency output. If the drive level is too low, it can prevent oscillator function completely. Generally, the drive level should be kept at the specified level required for high stability and adequate oscillator output.

Co — SHUNT CAPACITANCE (REF 3.7)

Holder capacitance commonly specified as 7 pf max., generally measured at 1 MHz.

MODES OF VIBRATION (REF 3.8)

Extensional, shear and flexure are the three common modes of vibration used in commercial applications. Both fundamental and overtone frequencies are possible within each of these modes.

Quartz Crystal Terms and Definitions

CRYSTAL CUTS (REF 3.8)

The plane or "cut" of a quartz element in relation to the optical axis of the quartz bar affects its piezoelectric properties. The AT-cut—at about a 35º to axis is the center of symmetry and is the reference for our AT-cut crystal specifications. The resulting element is a highly stable and accurate piezoelectric resonator. The resonant frequency range of the AT-cut is from 800 KHz to over 300 MHz including overtones. Frequency multipliers or frequency dividers can achieve lower and higher frequencies. Temperature change causes little variation in frequency with an AT-cut.

OVERTONE CRYSTALS (REF 3.8)

A crystal can vibrate at many frequencies, depending on the plane of cut, physical properties and geometry of the crystal bank. The lowest, or fundamental, frequency is the usual mode of output. Slight adjustments to the circuits can produce higher frequencies, such as 3rd, 5th, 7th and 9th harmonics (overtones). Overtone crystals are specially processed to maintain plane parallelism and surface finish to enhance overtone frequency performance.

AGING (REF 3.9)

The change in operating frequency over time. The rate of frequency change is fastest during the first 45 days of operation. The most common factors affecting aging include drive level, internal contamination, crystal surface change, ambient temperature, wire fatigue and frictional wear. All these problems can be minimized by proper circuit

GENERALIZED FORMULAS

* f_s = Series Resonant Frequency = $\frac{1}{2\pi\sqrt{L1C1}}$

* f_a = Antiresonant Frequency = $\frac{1\sqrt{C_1 + C_o}}{2\pi\sqrt{L_1C_1C_o}}$

* ΔF = Change in Frequency = $\frac{f_sC_1}{2(C_o + C_L)}$

* C_1 = Motional Capacitance = $\frac{2(C_o+C_L)\,\Delta F}{f_s}$

* L_1 = Motional Inductance = $\frac{1}{4\pi^2 f_s^2 C_1}$

* R_1 = Series Resonant Resistance = $\frac{2\pi f_s L_1}{Q}$

* r = Capacitance Ratio = $\frac{C_o}{C_1}$

* Q = Quality Factor = $\frac{2\pi f_s L_1}{R_1}$

* R_a = Antiresonant Resistance = $\frac{(C_L + C_o)^2 R_s}{C_L}$

* C_o = Crystal Shunt Capacitance

* C_L = Load Capacitance

WTL WORLD TECHNOLOGIES LTD.

Tight Tolerance Low Frequency — Technical Data: Quartz Crystals — **HC-51/U**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. _____

Date _____

Page: _____ of _____

Customer _____

Part No. _____ Part No. _____

Spec. No. _____ Dwg. or Spec. No.: _____ Rev. _____

ELECTRICAL

1.0 Operating Temperature Range _____ºC to _____ºC

2.0 Frequency Temperature Stability = ± _____% over _____ºC to _____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency		MHz
3.2 Frequency Calibration Tolerance		± %
3.3 Pullability		
3.4 Load Capacitance		pF
3.5 Effective Series Resistance		Ohms, Max.
3.6 Drive level-correlation/operating		mW
3.7 Shunt Capacitance		pF, Max.
3.8 Oscillation Mode		
3.9 Aging Rate		ppm/yr
3.10 Test Circuit	Saunders 150C	

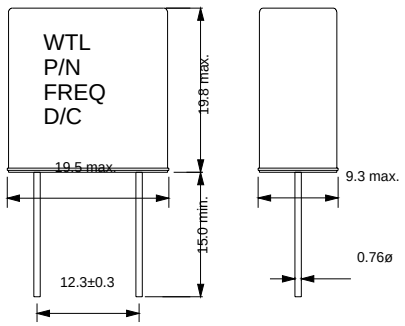
MECHANICAL

4.0 Holder Type: HC-51/U

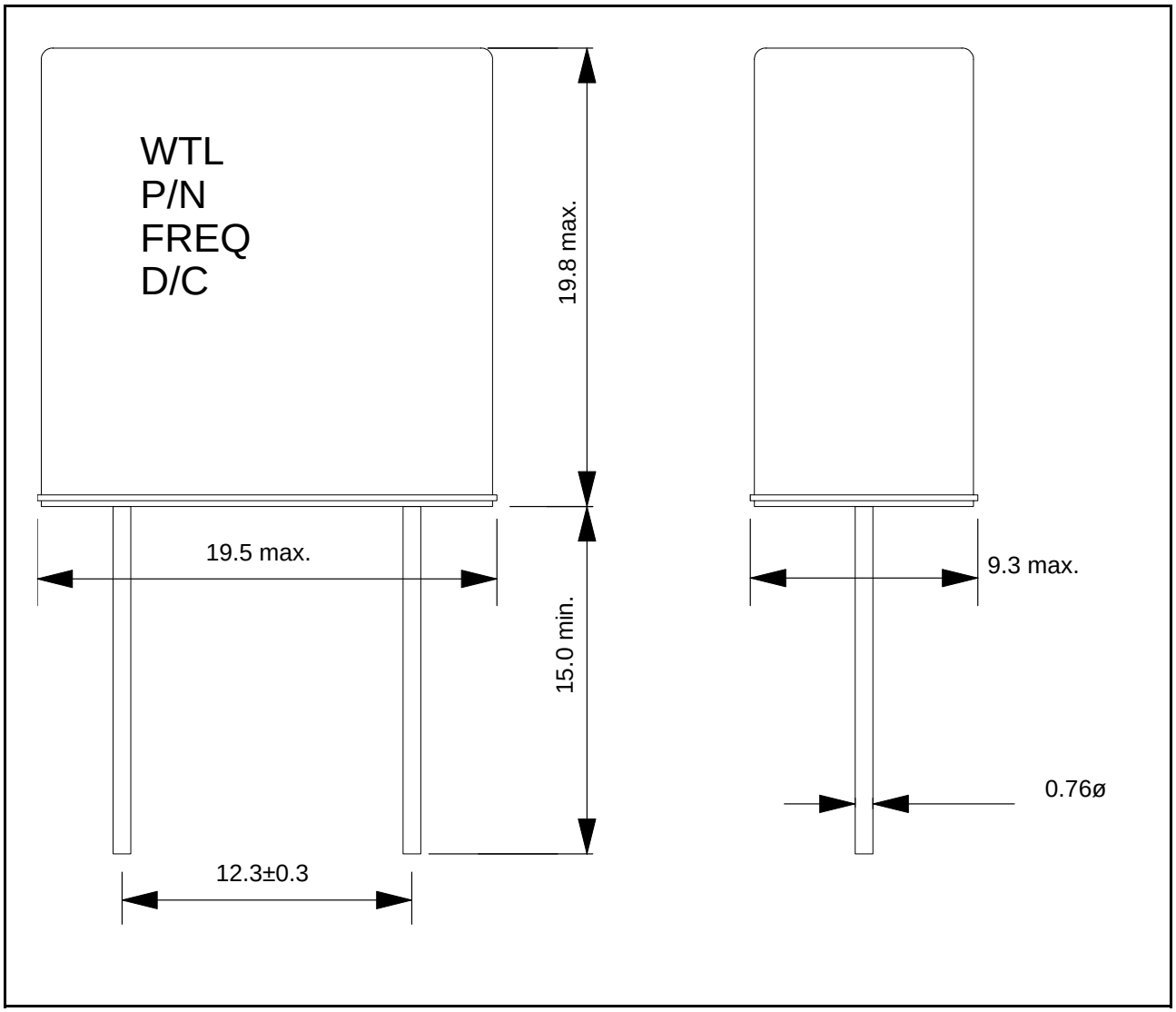
4.1 Marking: 4 lines on side.

OTHER SPECS

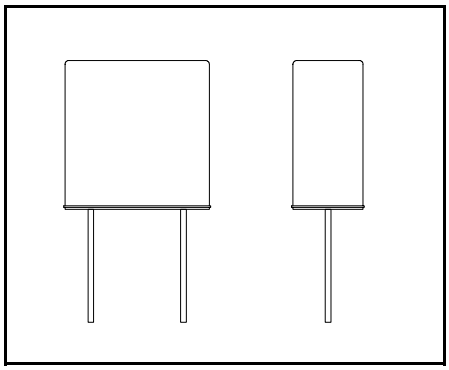
HC-51/U



HC-51/U



Enlarged View



Actual Size Shown Above 1=1

WTL WORLD TECHNOLOGIES LTD.

Technical Data: Quartz Crystals **HC-33/U**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No.

Date

Page: of

Customer

Part No. Part No.

Spec. No. Dwg. or Spec. No.: Rev.

ELECTRICAL

1.0 Operating Temperature Range _____ºC to _____ºC

2.0 Frequency Temperature Stability = ± _____% over _____ºC to _____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency		MHz
3.2 Frequency Calibration Tolerance		± %
3.3 Pullability		
3.4 Load Capacitance		pF
3.5 Effective Series Resistance		Ohms, Max.
3.6 Drive level-correlation/operating		mW
3.7 Shunt Capacitance		pF, Max.
3.8 Oscillation Mode		
3.9 Aging Rate		ppm/yr
3.10 Test Circuit	Saunders 150C	

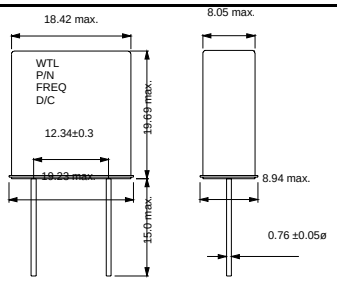
MECHANICAL

4.0 Holder Type: HC-33/U

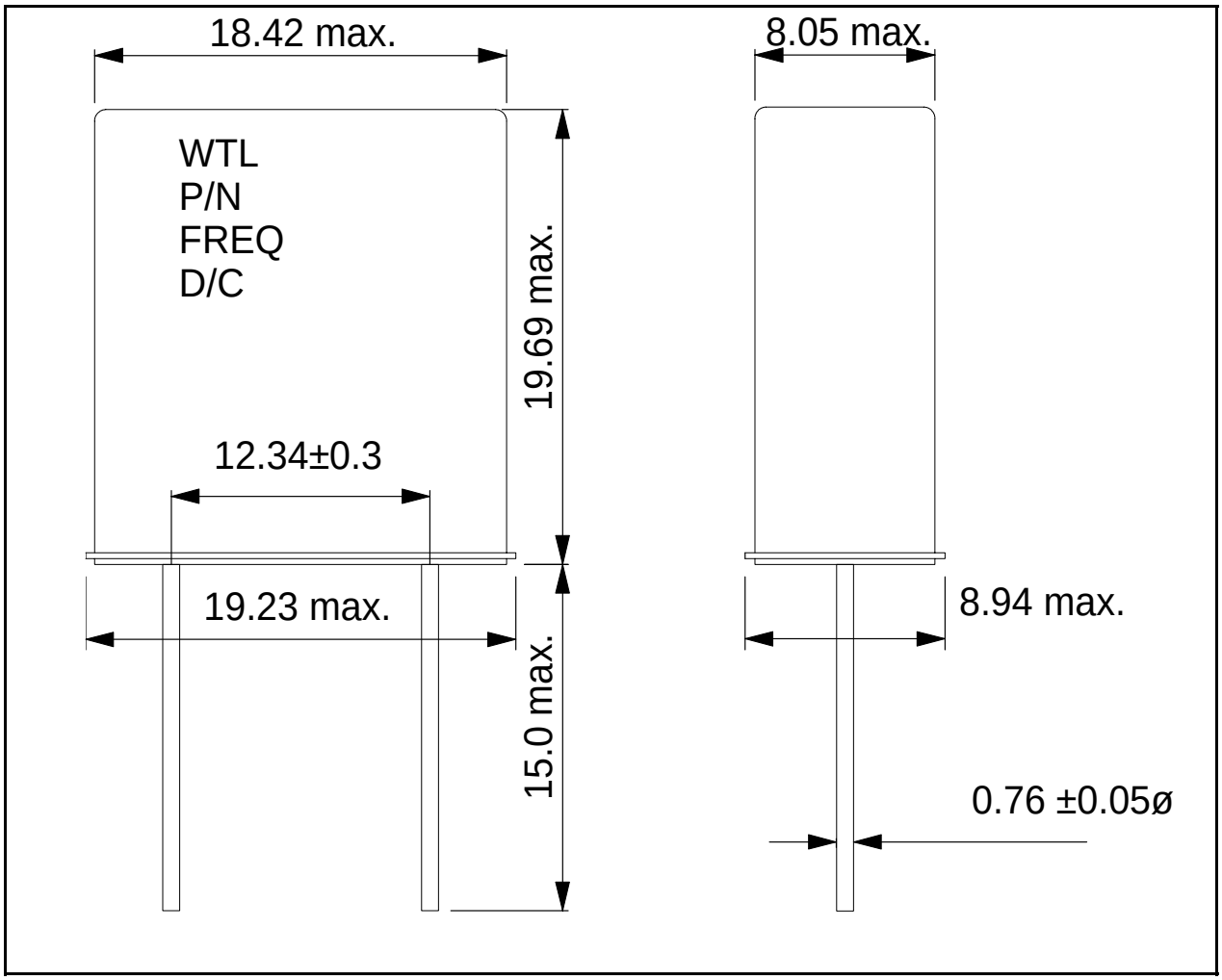
4.1 Marking: 4 lines on side.

OTHER SPECS

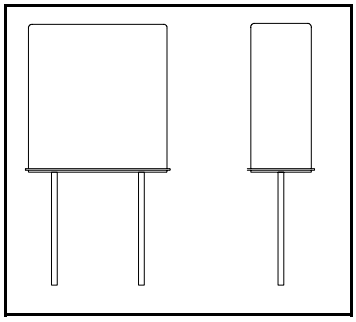
HC-33/U



Technical Data: Quartz Crystals **HC-33/U**



Enlarged View



Actual Size Shown Above 1=1

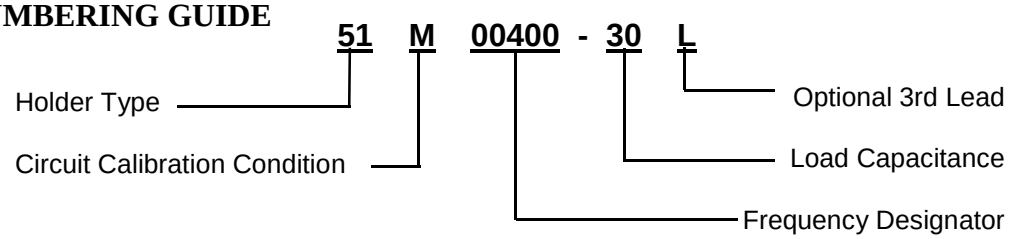
STANDARD SPECIFICATIONS

NOTES

1.	Holder type	HC-51/U, HC-33/U, HC-51/U-L OR HC-33/UL
2.	Frequency	120.000 kHz to 1.500000 MHz
3.	Calibration tolerance*	±50 ppm (±0.005%) at +25ºC
4.	Temperature stability tolerance*	±100 ppm (±0.01%) over -10ºC to +60ºC (DT/CT/SL-Cut)
		±100 ppm (±0.01%) over 20ºC to +70ºC (AT-Cut)
5.	Shunt capacitance	7 pF max.
6.	Drive Level	2 mW max.
7.	Cut	DT-Cut, CT-Cut, SL-Cut & AT-Cut
8.	Marking	WTL Part No., Frequency, Date Code.

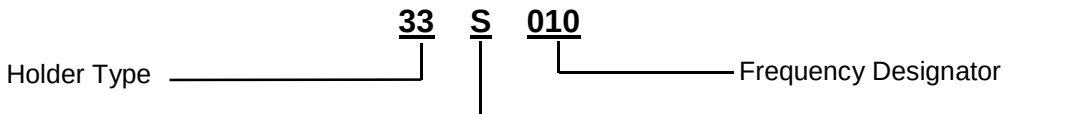
*Note: (3 & 4) Tight tolerance available to ± 2.5 ppm (0 + 70ºC) Call factory for tighter specifications

PART NUMBERING GUIDE



EXAMPLE

CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance=M C_L=13pF	400.000 kHz	HC-51/U-L	51M00400-30(L)
Parallel Resonance=M C_L=30 pF	400.000 kHz	HC-51/U	51M00400-30
Series Resonance=S	400.000 kHz	HC-51/U	51S00400



EXAMPLE

CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance=M C_L=13pF	1.000000 MHz	HC-33/U	33M010-13
Series Resonance=S	1.000000 MHz	HC-33/U	33S010
Series Resonance=S	1.000000 MHz	HC-33/U-L	33S010(L)

HC-51/U & HC-33/U Standard Frequencies

FREQUENCY KHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
120.000	00120	3000 DT-CUT
162.920	00162	3000 DT-CUT
188.000	00188	3000 DT-CUT
198.000	00198	3000 DT-CUT
200.000	00200	3000 DT-CUT
204.800	00204	3000 DT-CUT
207.476	00207	3000 DT-CUT
211.200	00211	3000 DT-CUT
262.144	00262	3000 DT-CUT
273.067	00273	3000 DT-CUT
307.200	00307	3000 CT-CUT
327.680	00327	3000 CT-CUT
400.000	00400	3000 SL-CUT
455.000	00455	3000 SL-CUT
460.800	00460	3000 SL-CUT
614.400	00614	3000 SL-CUT
750.000	00750	3000 SL-CUT
756.800	00756	3000 SL-CUT
819.200	00819	1500 AT-CUT
920.000	00920	1000 AT-CUT
921.600	00921	1000 AT-CUT
923.520	00923	1000 AT-CUT
960.000	00960	1000 AT-CUT
983.040	00983	1000 AT-CUT
998.500	00998	1000 AT-CUT
999.920	0099992	1000 AT-CUT
999.975	0099997	1000 AT-CUT

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
1.000000	010	600 AT-CUT
1.002500	01002	600 AT-CUT
1.008000	01008	600 AT-CUT
1.012000	0101	600 AT-CUT
1.024000	0102	600 AT-CUT
1.048576	0104	600 AT-CUT
1.152000	0115	600 AT-CUT
1.209600	01209	600 AT-CUT
1.228800	0122	600 AT-CUT
1.250000	0125	600 AT-CUT
1.269200	0126	600 AT-CUT
1.280000	0128	600 AT-CUT
1.310720	0131	600 AT-CUT
1.382400	0138	600 AT-CUT
1.475000	014	500 AT-CUT
1.500000	015	400 AT-CUT

Note: Special frequencies and tight specifications are available upon request.

WTL WORLD TECHNOLOGIES LTD.

Frequency Range 327.680 Khz to 200.00 Mhz Technical Data: Quartz Crystals **HC-49/U**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. 092700JF
Date 09/27/00
Page: 1 of 1

Customer EFFICIENT NETWORKS, INC.

Part No. 49M0499-20 Part No.

Spec. No. Dwg. or Spec. No.: Rev.

ELECTRICAL

1.0 Operating Temperature Range ____-10_____ºC to _____70_____ºC

2.0 Frequency Temperature Stability = ± ___0.003_____% over ___-10_____ºC to ___70_____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency	100.000000	MHz
3.2 Frequency Calibration Tolerance	0.003(+/--30PPM)	± %
3.3 Pullability	N/A	
3.4 Load Capacitance	20.0	pF
3.5 Effective Series Resistance	60.0	Ohms, Max.
3.6 Drive level-correlation/operating	1.5	mW
3.7 Shunt Capacitance	7.0	pF, Max.
3.8 Oscillation Mode	FUNDAMENTAL AT CUT	
3.9 Aging Rate	1.5	ppm/yr
3.10 Test Circuit	Saunders 150C	

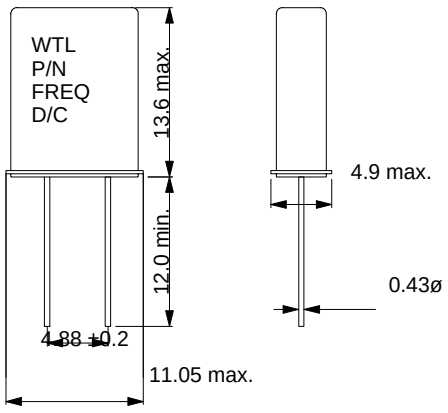
MECHANICAL

4.0 Holder Type: HC-49/U

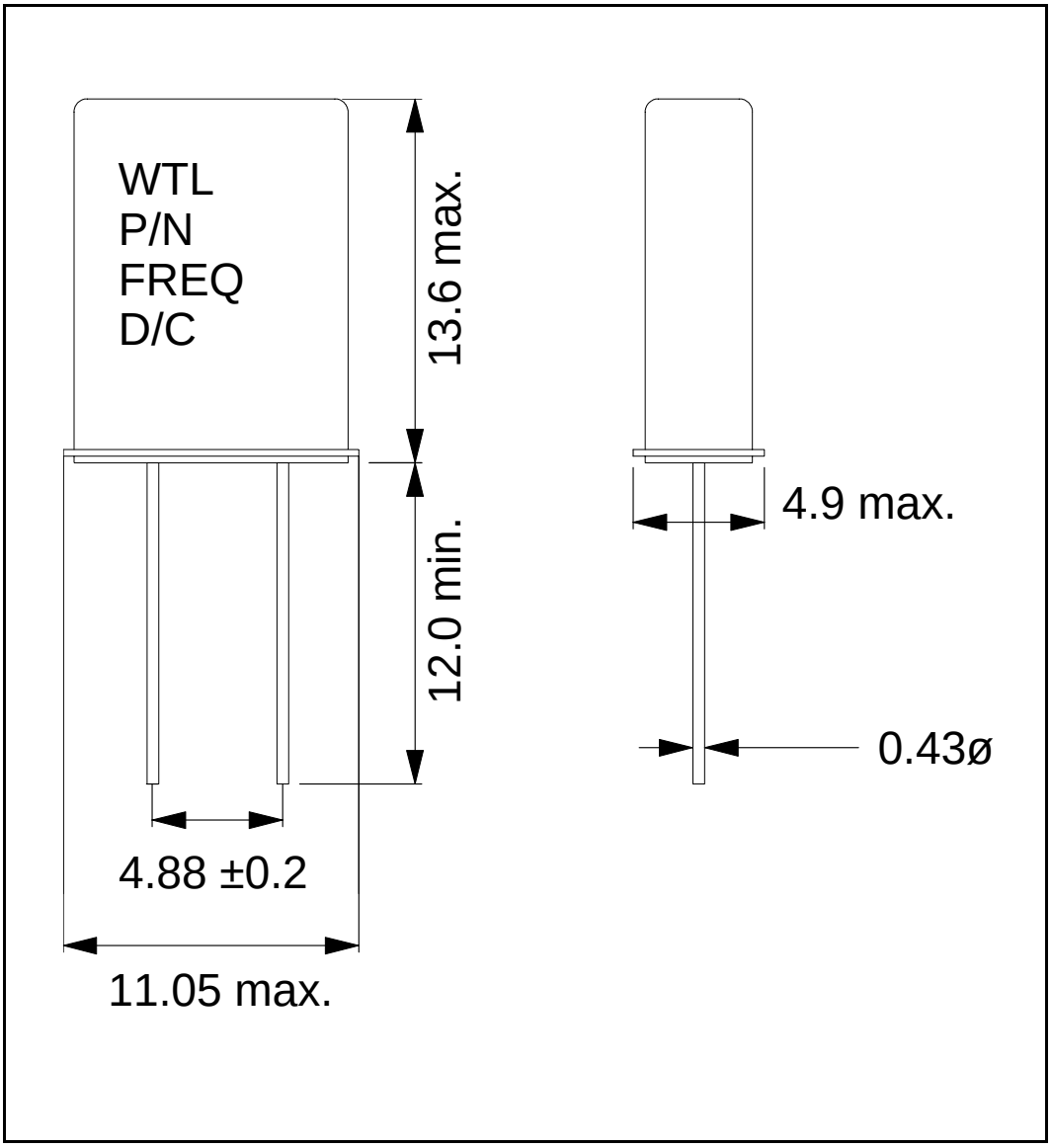
4.1 Marking: 4 lines on side.

OTHER SPECS

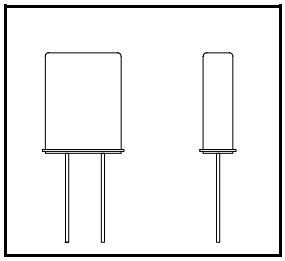
HC-49/U



HC-49/U

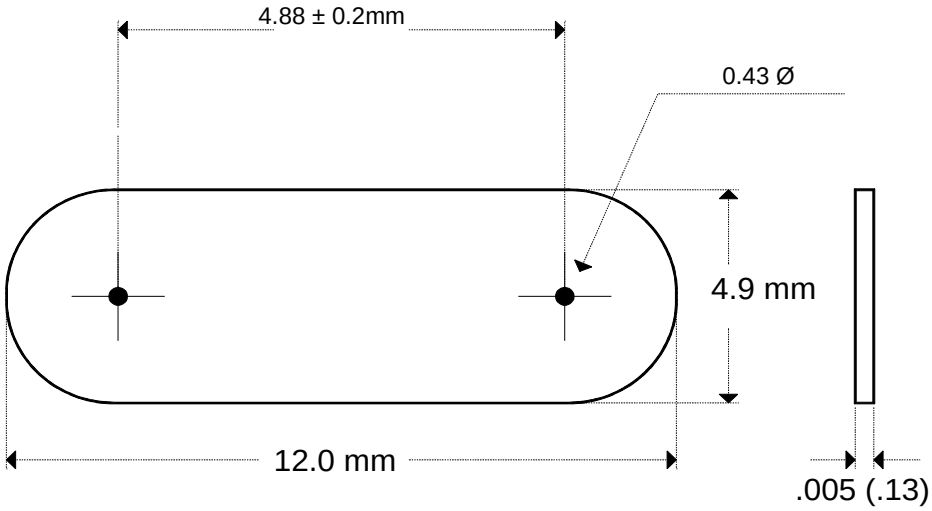


Enlarged View



Actual Size Shown Above 1=1

HC-49/U AND HC-49/US CRYSTAL SERIES BASE INSULATOR



PART NUMBER: WTL 12/2 BI
MATERIAL: MYLAR

WTL WORLD TECHNOLOGIES LTD.

Frequency Range 327.680 Khz to 200.00 Mhz Technical Data: Quartz Crystals **HC-49/U with 3rd**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. _____
Date _____
Page: _____ of _____

Customer _____

Part No. _____ Part No. _____

Spec. No. _____ Dwg. or Spec. No.: _____ Rev. _____

ELECTRICAL

1.0 Operating Temperature Range _____ºC to _____ºC

2.0 Frequency Temperature Stability = ± _____% over _____ºC to _____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency		MHz
3.2 Frequency Calibration Tolerance		± %
3.3 Pullability		
3.4 Load Capacitance		pF
3.5 Effective Series Resistance		Ohms, Max.
3.6 Drive level-correlation/operating		mW
3.7 Shunt Capacitance		pF, Max.
3.8 Oscillation Mode		
3.9 Aging Rate		ppm/yr
3.10 Test Circuit	Saunders 150C	

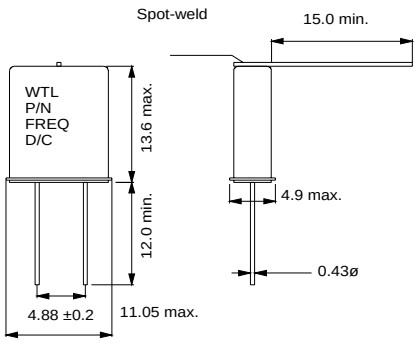
MECHANICAL

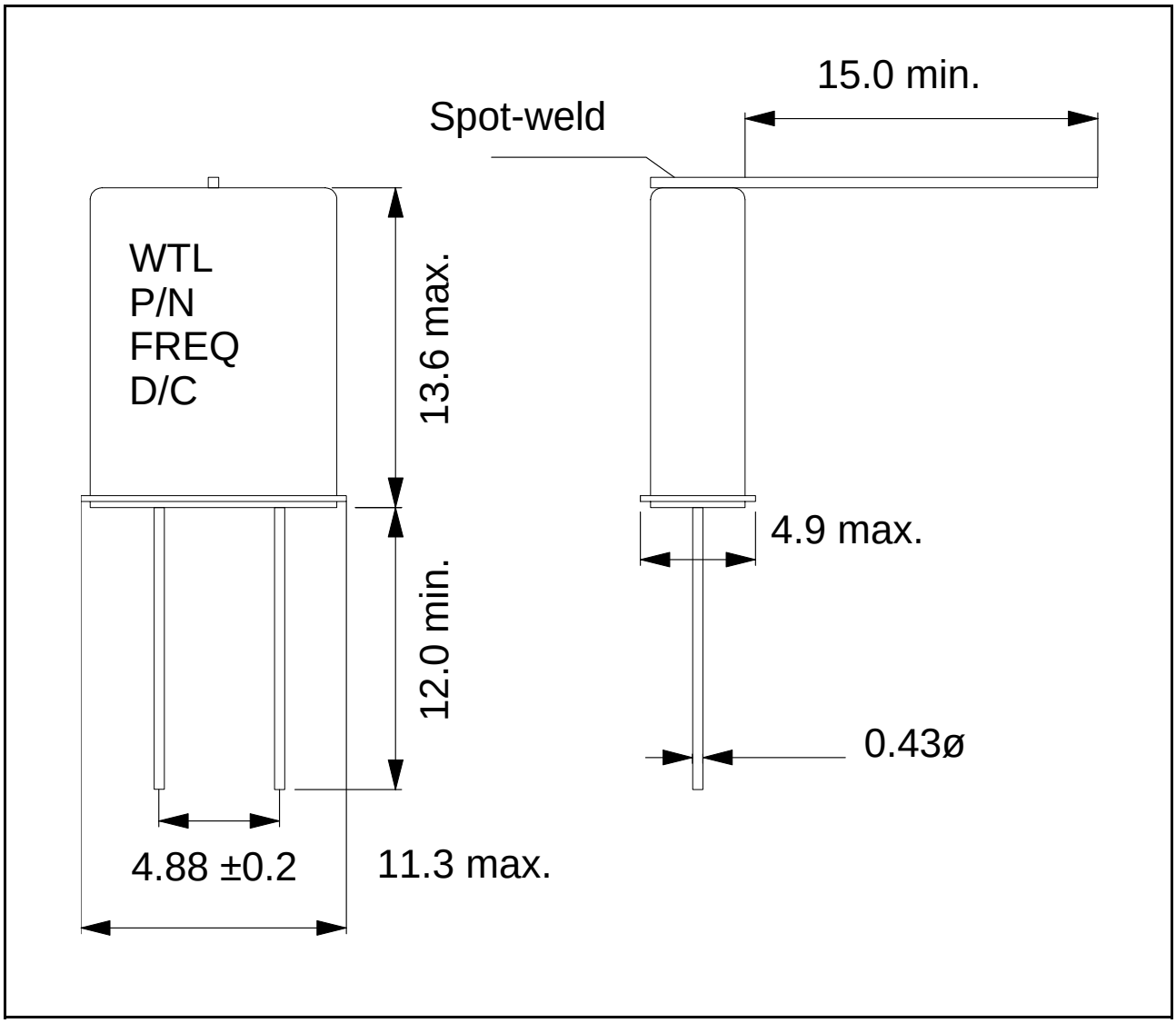
4.0 Holder Type: HC-49/U (With 3rd Lead)

4.1 Marking: 4 lines on side.

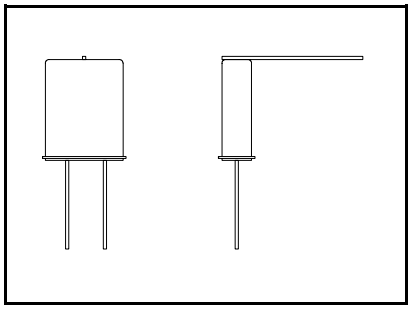
OTHER SPECS

HC-49/U with 3rd Lead





Enlarged View



Actual Size Shown Above 1=1

HC-49/U Family | Frequency Range 327.680 Khz to 200.00 Mhz | **HC-49/U Family**

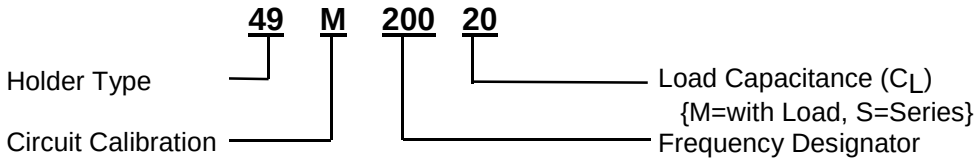
STANDARD SPECIFICATIONS

NOTES

1. Holder type	HC-49/U or HC-49/U-L	
2. Frequency	307.200kHz TO 200.000000MHz	
3. Calibration tolerance*	±50 ppm (±0.005%) at + 25ºC (DT-Cut & SL-Cut)	
	±30 ppm (±0.003%) at + 25ºC (AT-Cut)	
4. Temperature stability tolerance*	±50 ppm (±0.005%) over -20ºC to +70ºC (AT-Cut)	
	±100 ppm (±0.01%) over -10ºC to +60ºC (DT-Cut & SL-Cut)	
5. Shunt capacitance	7 pF max.	
6. Drive Level	2 mW max.	
7. Cut	DT-Cut, SL-Cut & AT-Cut	
8. Marking	WTL Part No., Frequency, Date Code.	

* NOTE: (3&4) Tight specifications available to ± 2.5 ppm

PART NUMBERING GUIDE



EXAMPLE

CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance C_L=13pF	1.843200 MHz	HC-49/U	49MO18-13
Parallel Resonance C_L=13pF	1.843200 MHz	HC-49/U-L	49MO18-13(L)
Series Resonance=S	1.843200 MHz	HC-49/U	49SO18

HC-49/U Standard Frequencies

Frequency Range 327.680 Khz to 200.00 Mhz

HC-49/U Family

FREQUENCY KHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
307.200	00307	3000 DT-CUT
327.680	00327	3000 DT-CUT
400.000	00400	3000 DT-CUT
409.600	00409	3000 DT-CUT
455.000	00455	3000 DT-CUT
500.000	00500	3000 DT-CUT
600.000	00600	3000 SL-CUT
614.400	00614	3000 SL-CUT
770.000	00770	3000 SL-CUT
800.000	00800	5000 SL-CUT
894.886	00894	5000 SL-CUT
896.000	00896	5000 SL-CUT
903.000	00903	5000 SL-CUT

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
1.000000	010	5000 SL-CUT
1.000800	010008	5000 SL-CUT
1.008000	01008	5000 SL-CUT
1.048576	0104	5000 SL-CUT
1.184000	011	5000 SL-CUT
1.228000	0122	600
1.536000	0153	600
1.550000	0155	600
1.682000	0168	500
1.843200	018	500
1.966000	019	400
2.000000	020	400
2.012160	0201	400
2.048000	0204	400
2.097152	0209	400
2.112000	0211	400
2.150400	0215	400
2.200000	022	400
2.304000	023	400
2.400000	0240	400
2.457600	024576	400
2.482000	0248	250
2.500000	025	250
2.560000	0256	250
2.562500	02562	250
2.583000	0258	250
2.764800	027	250
2.918400	0291	250
2.947861	0294	250
2.950000	0295	250
2.969600	0296	250
3.000000	030	180
3.072000	0307	180
3.200000	0320	180
3.276800	0327	180

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
3.304320	033	150
3.546864	0354	100
3.579545	035	100
3.582056	0358	100
3.686400	0368	100
3.884800	0388	100
3.897600	0389	100
3.932160	0393	100
3.993600	0399	100
3.999107	03999	100
4.000000	040	80
4.032000	0403	80
4.096000	0409	80
4.194304	041	80
4.194812	041948	80
4.433619	044	80
4.500000	045	60
4.608000	046	60
4.623000	0462	60
4.800000	048	60
4.915200	049	60
4.956200	0495	60
5.000000	050	50
5.068800	0506	50
5.120000	0512	50
5.185000	0518	50
5.200000	052	50
5.242880	0524	50
5.505000	05505	50
5.529600	0552	50
5.760000	057	50
5.898240	058	50
5.990400	059	50
6.000000	060	40
6.036800	0603	40
6.144000	061	40
6.176000	0617	40
6.400000	064	40
6.553600	0655	40
7.040000	0704	30
7.159090	071	30
7.200000	072	30
7.372660	073726	30
7.372800	073	30
7.373000	07373	30
8.000000	080	30
8.181817	0818	30
8.192000	08192	30
8.867238	088	30
9.000000	090	25
9.065000	0906	25
9.216000	092	25
9.600000	096	25

Note: Special frequencies and specifications are available upon request.

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
9.728000	0972	25
9.830400	098	25
10.000000	100	25
10.080000	1008	25
10.137600	1013	25
10.240000	1024	25
10.245000	10245	25
10.483200	104	25
10.598400	105	25
10.670000	1067	25
10.687500	1068	25
10.695000	1069	25
10.700000	107	25
10.730000	1073	25
10.738635	10738	25
10.920000	109	25
11.000000	110	25
11.059200	1105	25
11.170000	1117	25
11.250000	112	25
11.340000	113	25
11.980800	1198	25
11.981350	119	25
12.000000	120	25
12.003000	12003	25
12.004000	12004	25
12.004500	120045	25
12.096000	1209	25
12.288000	122	25
12.299520	12299	25
12.750000	127	25
13.200000	132	20
13.206250	13206	20
13.237500	1323	20
13.560000	1356	20
13.824000	1382	20
14.000000	140	20
14.218000	142	20
14.318180	143	20
14.745600	147	20
14.925000	1492	20
14.976000	1497	20
15.000000	150	20
15.206000	15206	20
15.360000	153	20
15.728640	157	20
15.974400	1597	20
15.988780	1598	20
16.000000	160	20
16.257000	162	20
16.384000	163	20
16.896000	1689	20
17.203200	172	20
17.734470	177	20
18.000000	180	20
18.260000	182	20
18.432000	184	20
18.480000	1848	20
18.528000	185	20
18.867000	188	20
18.868000	18868	20
18.869600	18869	20
18.954000	189	20
19.200000	192	20
19.354000	193	20
19.655000	1965	20
19.660800	196	20
20.000000	200	20
20.164800	201	20
20.338000	2033	20
20.342000	2034	20
20375040	2037	20
20.480000	204	20
20.685500	2068	20
20.698000	2069	20
20.704250	20704	20
20.721040	2072	20
20.735500	2073	20
21.300000	213	20
21.855000	218	20
22.118400	221	20
22.198400	22198	20
23.961600	239	20
24.000000	240	20
24.576000	245	20*
25.000000	250	20*
25.175000	2517	20*
25.216000	252	20*
26.520000	2652	20*
26.540000	2654	20*
26.560000	2656	20*
26.590000	2659	20*
26.964000	2696	20*
26.975000	2697	20*
26.995000	2699	20*
27.000000	270	20*
27.010000	2701	20*
27.015000	27015	20*
27.045000	2704	20*
27.455000	2745	20*
27.465000	2746	20*
27.648000	276	20*
28.322000	2832	20*
28.636360	286	20*
30.000000	300	20*

*** Also available in 3rd Overtone Mode Upon Request**

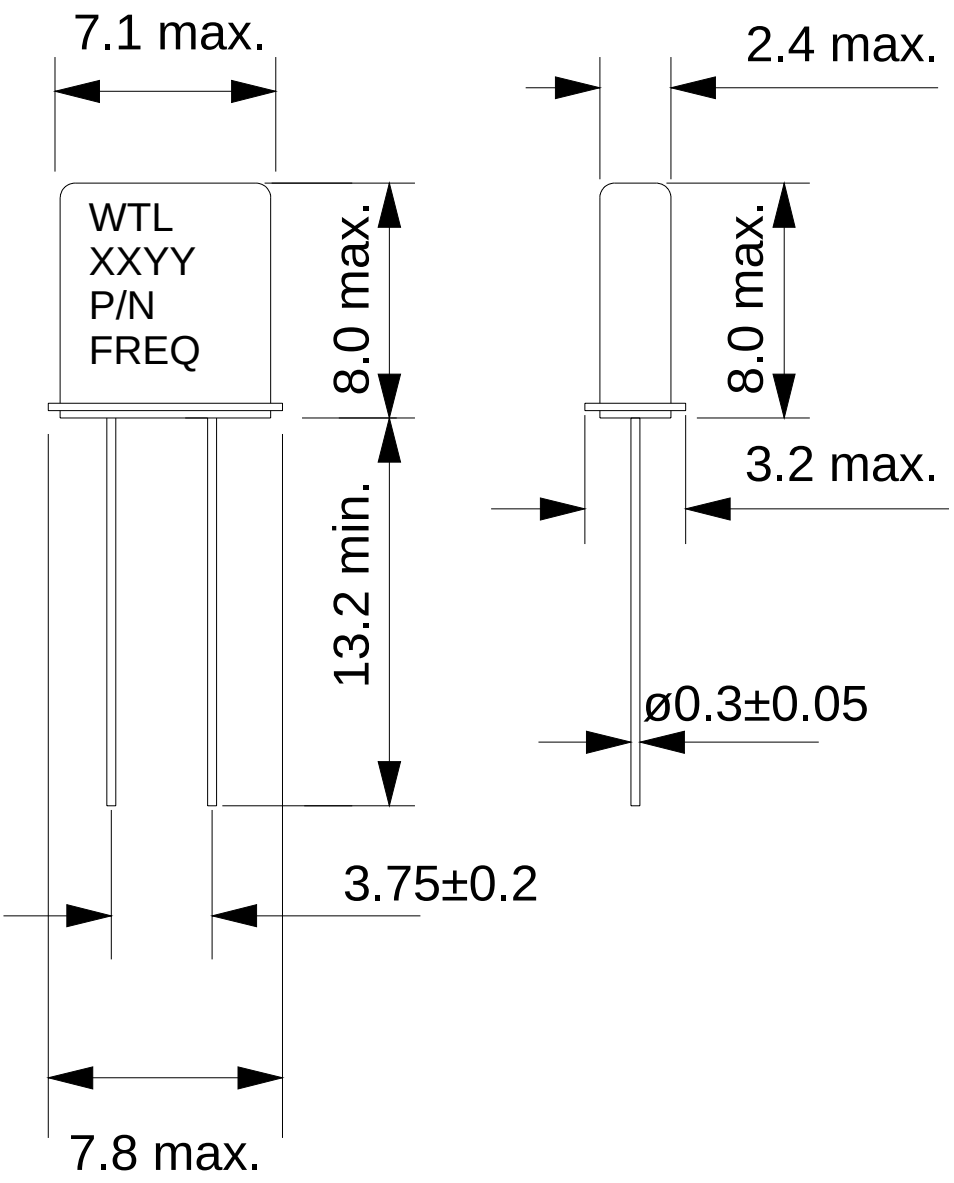
HC-49/U Standard Frequencies

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
32.000000	320	40 3OT
35.935000	359	40 3OT
36.000000	360	40 3OT
37.075000	3707	40 3OT
37.100000	371	40 3OT
37.112500	3711	40 3OT
37.175000	3717	40 3OT
40.000000	400	40 3OT
40.225000	4022	40 3OT
40.230000	4023	40 3OT
40.685000	406	40 3OT
44.736000	447	40 3OT
47.998000	479	40 3OT
48.000000	480	40 3OT
49.405000	494	40 3OT
49.435000	4943	40 3OT
49.860000	498	40 3OT
52.000000	520	40 3OT
52.075000	5207	40 3OT
52.100000	521	40 3OT
52.112500	5211	40 3OT
52.175000	5217	40 3OT
57.535000	5753	40 3OT
57.590000	5759	40 3OT
80.000000	800	60 3OT
100.000000	1000	60 3OT
121.500000	1215	60 3OT
139.253000	1392	80 3OT
140.355000	1403	80 3OT
152.650000	1526	80 3OT
200.000000	2000	80 50T

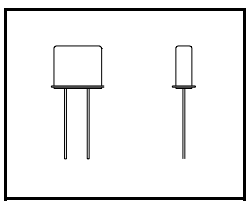
HC-49/U

Frequency Range 327.680 Khz to 200.00 Mhz

UM-1

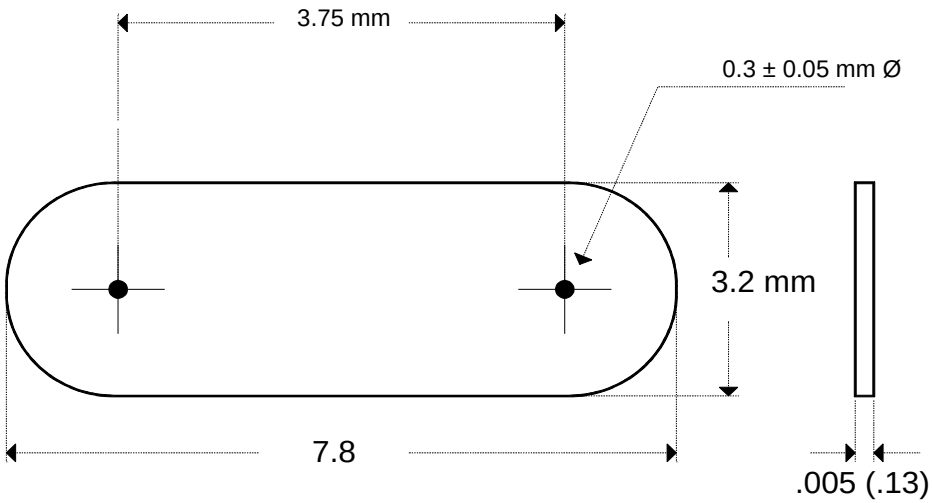


Enlarged View



Actual Size Shown Above 1=1

UM-1,4 & 5 CRYSTAL SERIES BASE INSULATOR



PART NUMBER: WTL 7.8/2 BI
MATERIAL: MYLAR

WTL WORLD TECHNOLOGIES LTD. Frequency Range 327.680 Khz to 200.00 Mhz **UM-1**

Technical Data: Quartz Crystals

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. _____

Date _____

Page: _____ of

Customer _____

Part No. _____ Part No. _____

Spec. No. Dwg. or Spec. No.: _____ Rev. _____

ELECTRICAL

1.0 Operating Temperature Range _____ºC to _____ºC

2.0 Frequency Temperature Stability = ± _____% over _____ºC to _____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency		MHz
3.2 Frequency Calibration Tolerance		± %
3.3 Pullability		
3.4 Load Capacitance		pF
3.5 Effective Series Resistance		Ohms, Max.
3.6 Drive level-correlation/operating		mW
3.7 Shunt Capacitance		pF, Max.
3.8 Oscillation Mode		
3.9 Aging Rate		ppm/yr
3.10 Test Circuit	Saunders 150C	

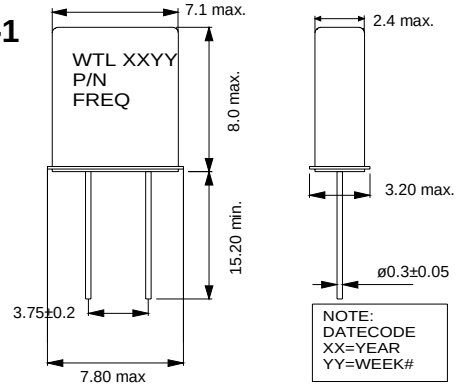
MECHANICAL

4.0 Holder Type: UM-1

4.1 Marking: 3 lines on side.

OTHER SPECS

UM-1



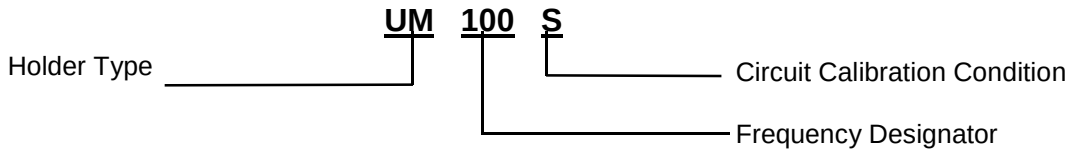
UM-1 Family **- TIGHT TOLERANCE -** **UM-1**

STANDARD SPECIFICATIONS

NOTES

1. Holder type	UM-1	
2. Frequency	1.000000 MHz to 200.000000 MHz	
*3. Calibration tolerance	±50 ppm (±0.005%) at + 25ºC (SL-Cut)	
	±30 ppm (±0.003%) at + 25ºC (AT-Cut)	
*4. Temperature stability tolerance	±100 ppm (±0.01%) over - 10ºC to +60ºC (SL-Cut)	
	±50 ppm (±0.005%) over -20ºC to +70ºC (AT-Cut)	
5. Shunt capacitance	7 pF max.	
6. Drive Level	0.5 mW max.	
7. Cut	AT-Cut & BT-Cut	
8. Marking	WTL Part No., Frequency, Date Code.	

PART NUMBERING GUIDE



EXAMPLE

CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance C_L=10pF	10.000000 MHz	UM-1	UM100-10
Series Resonance=S	10.000000 MHz	UM-1	UM100S

*** Note: Calibration tolerance available to ± 2.5 ppm.**
Temperature stability tolerance available to ± 2.5 ppm.
Pullability spec. available.

UM-1 Standard Frequencies

- TIGHT TOLERANCE -

UM-1

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
1.000000	010	5000 SL-CUT
1.008000	01008	5000 SL-CUT
1.048576	0104	5000 SL-CUT
1.080000	0108	5000 SL-CUT
1.200000	012	5000 SL-CUT
3.579545	035	200
4.000000	040	180
4.406250	04406	180
5.000000	050	150
5.003000	05003	150
5.120000	0512	150
5.997000	059	150
6.000000	060	120
6.003000	06003	120
6.144000	061	120
6.400000	064	120
6.553600	0655	120
8.000000	080	80
8.192000	081	80
9.216000	092	60
9.600000	096	60
9.827500	0982	60
10.000000	100	60
10.004600	10004	60
10.005000	10005	60
10.245000	10245	60
10.702800	10702	60
10.730000	1073	60
11.059200	1105	60
11.981350	119	60
12.000000	120	60
12.288000	122	60
12.352000	123	60
12.800000	128	60
13.107200	131	30
13.500000	135	30
14.318180	143	30
14.745600	147	30
15.000000	150	30
15.135400	151	30
15.360000	153	30
15.435000	154	30
16.000000	160	30
16.384000	163	30
16.633300	1663	30
17.734475	177	30
19.636200	1963	30
19.660800	196	30

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
20.000000	200	30
20.945000	209	30
21.480000	214	30
21.855000	218	30
22.000000	220	30
22.068960	2206	30
22.118400	221	30
22.248000	222	30
22.500000	225	30
24.000000	240	30
24.000140	240001	30
25.000000	250	30
26.150000	261	60 *3OT
26.995000	269	60 *3OT
27.010000	2701	60 *3OT
27.055000	2705	60 *3OT
29.345000	293	60 *3OT
29.500000	295	60 *3OT
30.000000	300	60 *3OT
30.865000	308	60 *3OT
32.000000	320	60 *3OT
32.424000	3242	60 3OT
32.785200	327	60 3OT
36.000000	360	60 3OT
37.000000	270	60 3OT
38.400000	284	60 3OT
40.000000	400	60 3OT
40.210000	402	60 3OT
40.960000	409	60 3OT
45.158400	451	60 3OT
49.431700	494	60 3OT
50.348330	503	60 3OT
52.372000	523	60 3OT
54.295000	542	60 3OT
54.466400	544	60 3OT
57.600000	576	60 3OT
57.741600	5774	60 3OT
57.767000	5776	60 3OT
66.662500	666	60 3OT
69.187500	691	60 3OT
70.400000	704	60 3OT
80.000000	800	60 3OT
81.920000	819	60 3OT
92.940500	929	60 3OT
100.000000	1000	60 3OT
110.000000	1100	60 3OT
120.000000	1200	60 3OT
160.000000	1600	60 3OT
200.000000	2000	60 5OT

*** Also available in Fundamental Mode Upon Request.**

WTL WORLD TECHNOLOGIES LTD.

- TIGHT TOLERANCE - Technical Data: Quartz Crystals **UM-4 & UM-5**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. 090500JF
Date SEPTEMBER 5, 2000
Page: 1 of 2

Customer EFFICIENT NETWORKS, INC.

Part No. 5UM100-S/5OT/CM Part No.

Spec. No. WTL SPECIFICATION Dwg. or Spec. No.: Rev.

ELECTRICAL

1.0 Operating Temperature Range _____0_____ºC to ____70_____ºC

2.0 Frequency Temperature Stability = ± ___0.003_____% over ___0_____ºC to ____70_____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency	100.000000	MHz
3.2 Frequency Calibration Tolerance	0.003(+/-3PPM)	± %
3.3 Pullability	N/A	
3.4 Load Capacitance	SERIES	pF
3.5 Effective Series Resistance	60.0	Ohms, Max.
3.6 Drive level-correlation/operating	0.5	mW
3.7 Shunt Capacitance	7.0	pF, Max.
3.8 Oscillation Mode	FIFTH OVERTONE AT CUT	
3.9 Aging Rate	0.5	ppm/yr
3.10 Test Circuit	Saunders 150C	

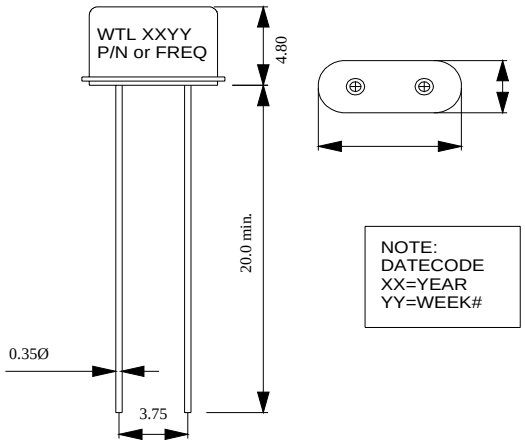
MECHANICAL

4.0 Holder Type: UM-5

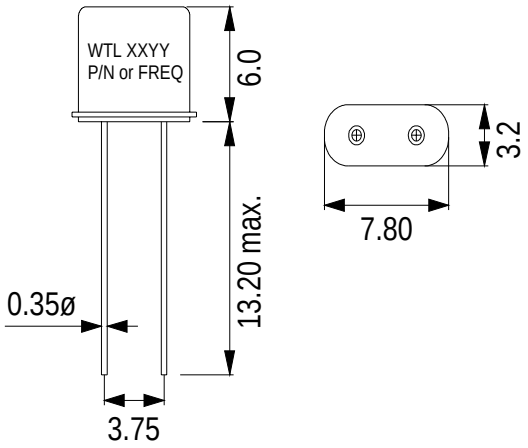
4.1 Marking: 2 lines on side.

OTHER SPECS

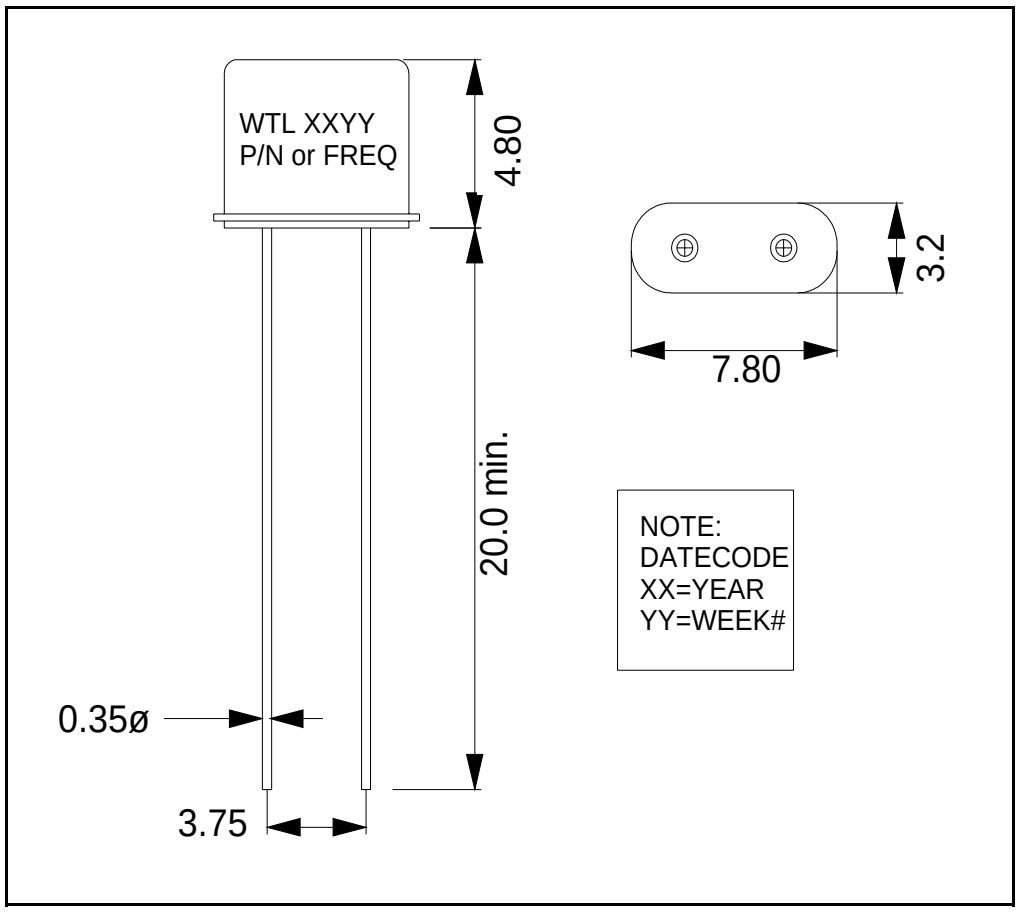
UM-4



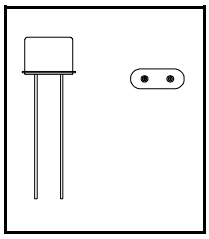
UM-5



UM-4



Enlarged View



Actual Size Shown Above 1=1

UM-4 Family

- TIGHT TOLERANCE -

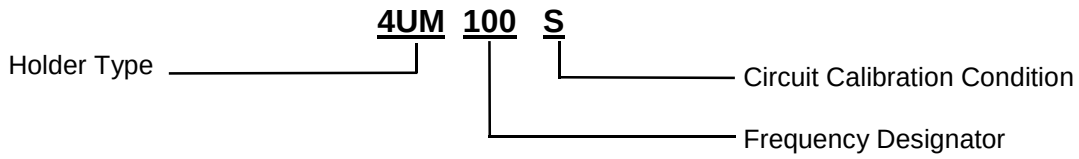
UM-4 & UM-5

STANDARD SPECIFICATIONS

NOTES

1. Holder type	UM-4 & UM-5	
2. Frequency	10.000000 MHz to 200.000000 MHz	
*3. Calibration tolerance	±50 ppm (±0.005%) at + 25ºC (SL-Cut)	
	±30 ppm (±0.003%) at + 25ºC (AT-Cut)	
*4. Temperature stability tolerance	±100 ppm (±0.01%) over - 10ºC to +60ºC (SL-Cut)	
	±50 ppm (±0.005%) over -20ºC to +70ºC (AT-Cut)	
5. Shunt capacitance	7 pF max.	
6. Drive Level	0.5 mW max.	
7. Cut	AT-Cut & BT-Cut	
8. Marking	WTL Part No., Frequency, Date Code.	

PART NUMBERING GUIDE

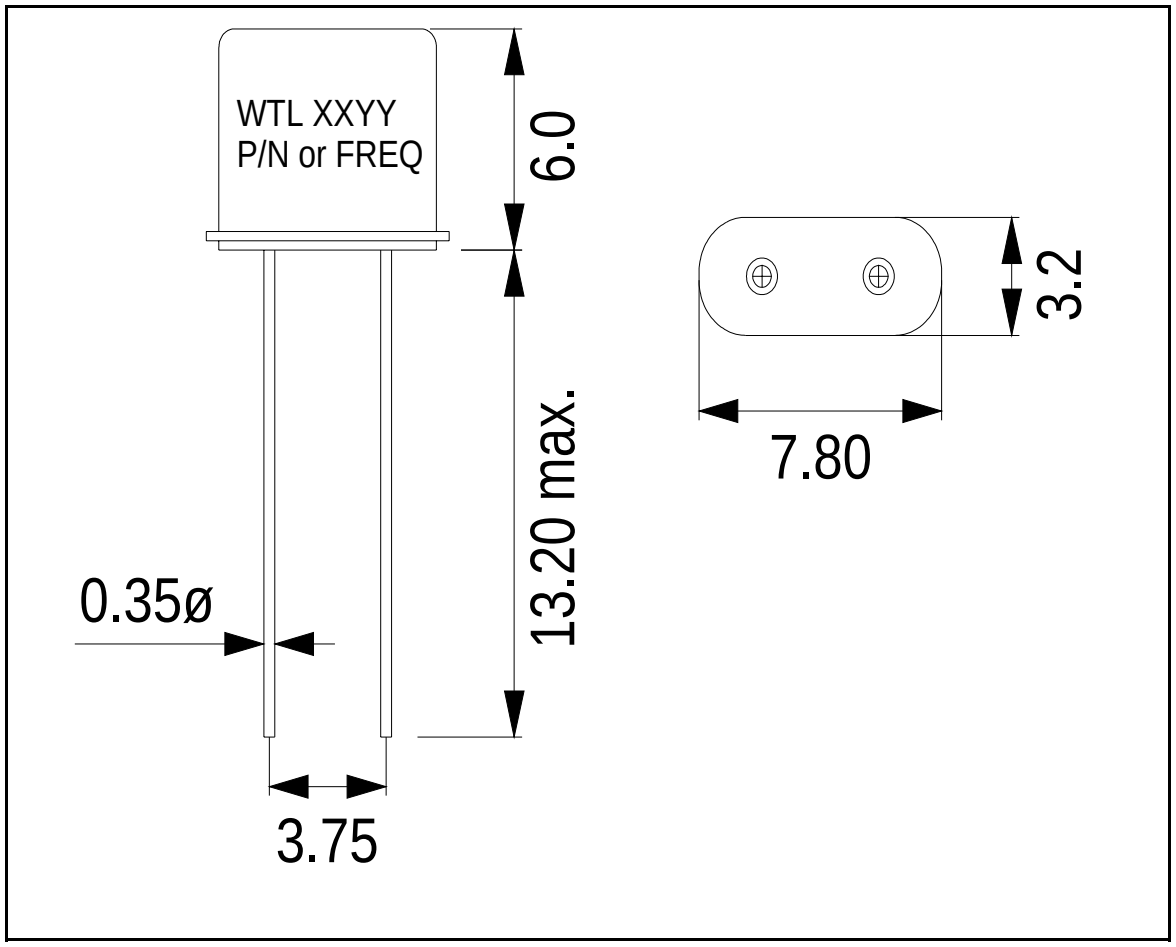


EXAMPLE

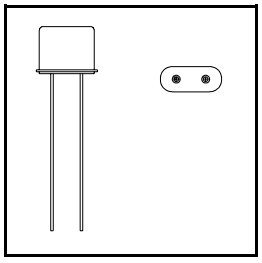
CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance C_L=10pF	10.000000 MHz	UM-4	4UM100-10
Series Resonance=S	10.000000 MHz	UM-4	4UM100S

*** Note: Calibration tolerance available to ± 2.5 ppm.**
Temperature stability tolerance available to ± 2.5 ppm.
Pullability spec. available.

UM-5 Family



Enlarged View



Actual Size Shown Above 1=1

UM-4 Standard Frequencies - TIGHT TOLERANCE - UM-4 & UM-5

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
10.000000	100	60
12.000000	120	60
12.288000	122	60
12.352000	123	60
12.800000	128	60
13.107200	131	30
13.500000	135	30
14.318180	143	30
14.745600	147	30
15.000000	150	30
15.135400	151	30
15.360000	153	30
15.435000	154	30
16.000000	160	30
16.384000	163	30
16.633300	1663	30
17.734475	177	30
19.636200	1963	30
19.660800	196	30
20.000000	200	30
20.945000	209	30
21.480000	214	30
21.855000	218	30
22.000000	220	30
22.068960	2206	30
22.118400	221	30
22.248000	222	30
22.500000	225	30
24.000000	240	30
24.000140	240001	30
25.000000	250	30
26.150000	261	60 *3OT
26.995000	269	60 *3OT
27.010000	2701	60 *3OT
27.055000	2705	60 *3OT
29.345000	293	60 *3OT
29.500000	295	60 *3OT
30.000000	300	60 *3OT
30.865000	308	60 *3OT
32.000000	320	60 *3OT
32.424000	3242	60 3OT
32.785200	327	60 3OT
36.000000	360	60 3OT
37.000000	270	60 3OT
38.400000	284	60 3OT
40.000000	400	60 3OT
40.210000	402	60 3OT
40.960000	409	60 3OT
45.158400	451	60 3OT
49.431700	494	60 3OT
50.348330	503	60 3OT
52.372000	523	60 3OT
54.295000	542	60 3OT
54.466400	544	60 3OT
57.600000	576	60 3OT
57.741600	5774	60 3OT
57.767000	5776	60 3OT
66.662500	666	60 3OT
69.187500	691	60 3OT
70.400000	704	60 3OT
80.000000	800	60 3OT
81.920000	819	60 3OT
92.940500	929	60 3OT
100.000000	1000	60 3OT
110.000000	1100	60 3OT
120.000000	1200	60 3OT
200.000000	2000	60 3OT

*** Also available in Fundamental Mode Upon Request.**

WTL WORLD TECHNOLOGIES LTD.

Frequency Range 3.000000 Mhz to 125.000000 Mhz Technical Data: Quartz Crystals **HC-49/U-4H**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No. 092099JF
Date SEPTEMBER 20, 99
Page: 1 of 1

Customer P-COM, INC.

Part No. 4H221184-20 Part No. 14450-221

Spec. No. CUSTOMER SPECS Dwg. or Spec. No.: 14450 Rev.

ELECTRICAL

1.0 Operating Temperature Range ____-10_____ºC to _____70_____ºC

2.0 Frequency Temperature Stability = ± __0.005____% over ____-10_____ºC to ____70_____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency	22.118400	MHz
3.2 Frequency Calibration Tolerance	0.003(+/-30PPM)	± %
3.3 Pullability	N/A	
3.4 Load Capacitance	20.0	pF
3.5 Effective Series Resistance	40.0	Ohms, Max.
3.6 Drive level-correlation/operating	0.5	mW
3.7 Shunt Capacitance	7.0	pF, Max.
3.8 Oscillation Mode	FUNDAMENTAL AT CUT	
3.9 Aging Rate	1.5	ppm/yr
3.10 Test Circuit	Saunders 150C	

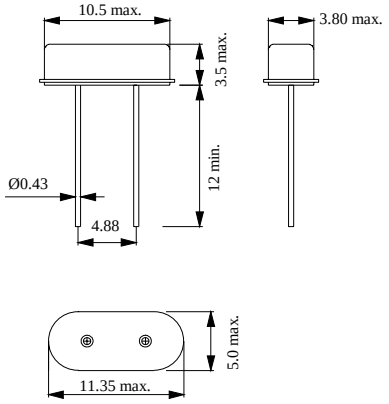
MECHANICAL

4.0 Holder Type: HC-49/U-4H

4.1 Marking: One line on top.

OTHER SPECS

HC-49/U-4H



WTL WORLD TECHNOLOGIES LTD.

Technical Data: Quartz Crystals **HC-49/U-4H(3L)**

QUARTZ CRYSTAL SPECIFICATIONS

Ref No.

Date

Page: of

Customer

Part No. Part No.

Spec. No. Dwg. or Spec. No.: Rev.

ELECTRICAL

1.0 Operating Temperature Range _____ºC to _____ºC

2.0 Frequency Temperature Stability = ± _____% over _____ºC to _____ºC.

3.0 Specifications at 25ºC ± 2ºC:	Value	Units
3.1 Frequency		MHz
3.2 Frequency Calibration Tolerance		± %
3.3 Pullability		
3.4 Load Capacitance		pF
3.5 Effective Series Resistance		Ohms, Max.
3.6 Drive level-correlation/operating		mW
3.7 Shunt Capacitance		pF, Max.
3.8 Oscillation Mode		
3.9 Aging Rate		ppm/yr
3.10 Test Circuit	Saunders 150C	

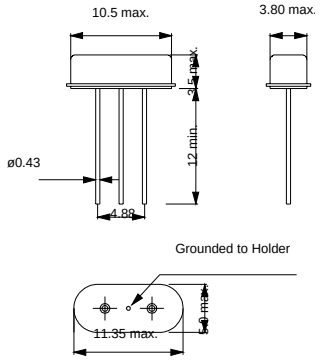
MECHANICAL

4.0 Holder Type: HC-49/U-4H

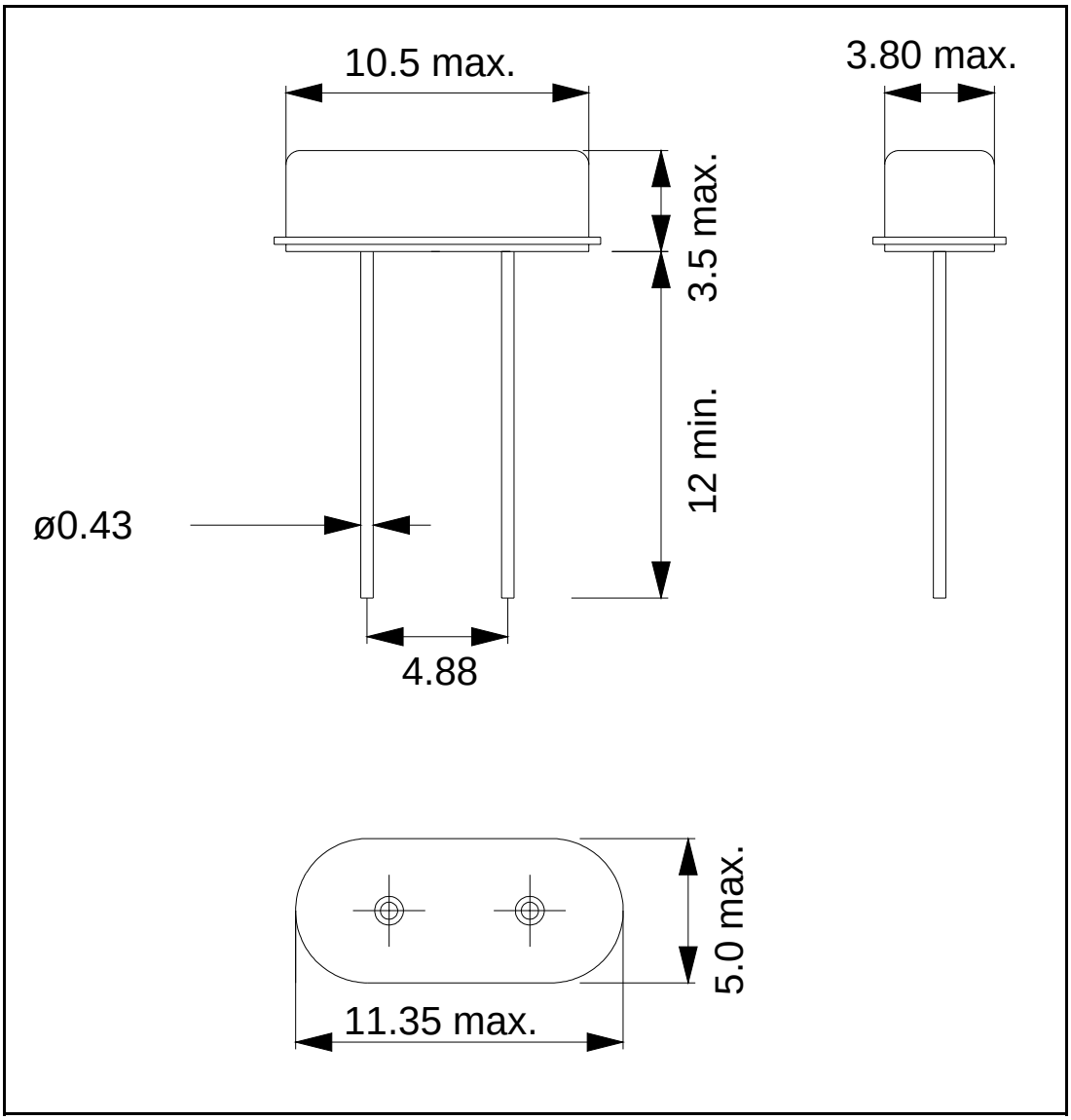
4.1 Marking: One line on top.

OTHER SPECS

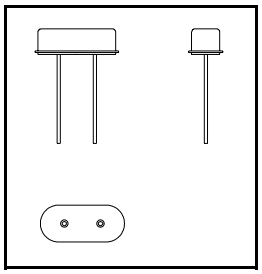
HC-49/U-4H(3L)



HC-49/U-4H



Enlarged View

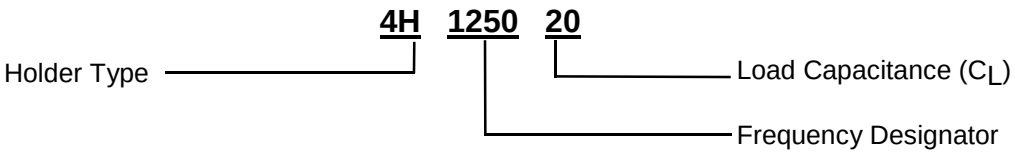


Actual Size Shown Above 1=1

HC-49/U-4H Family **- TIGHT TOLERANCE -** **HC-49/U-4H**

STANDARD SPECIFICATIONS

		NOTES
1. Holder type	HC-49/U-4H or HC-49/U-4H (3L)	
2. Frequency	3.000000 MHz to 125.000000 MHz	
*3. Calibration tolerance	±50 ppm (±0.005%) at + 25ºC	
*4. Temperature stability tolerance	±30 ppm (±0.003%) at + 25ºC (AT-Cut)	
	±50 ppm (±0.005%) over -20ºC to +70ºC (AT-Cut)	
	±100 ppm (±0.01%) over - 10ºC to +60ºC (BT-Cut)	
5. Shunt capacitance	7 pF max.	
6. Drive Level	0.5 mW max.	
7. Cut	AT-Cut & BT-Cut	
8. Marking	WTL Part No., Frequency, Date Code.	

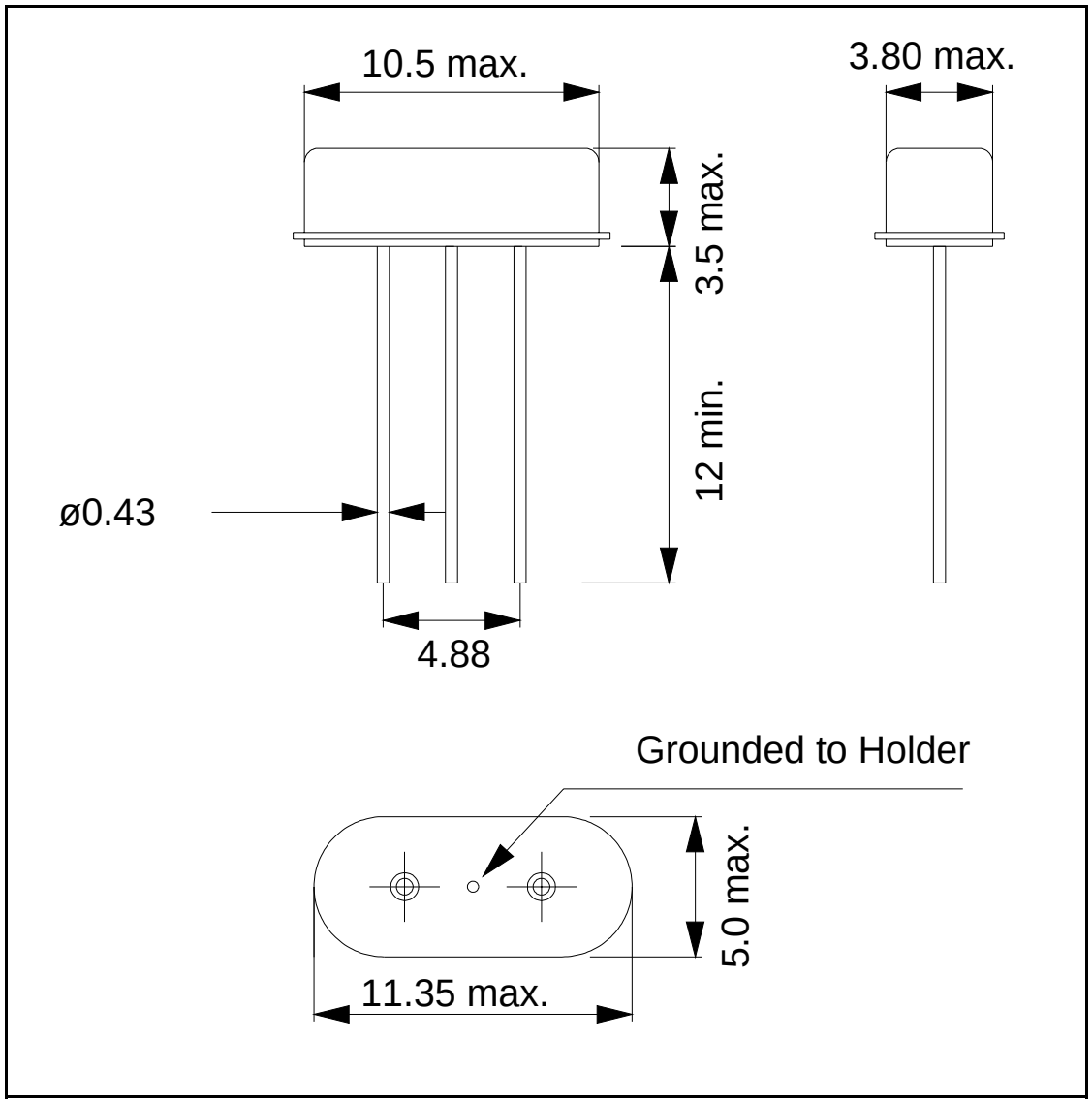


EXAMPLE

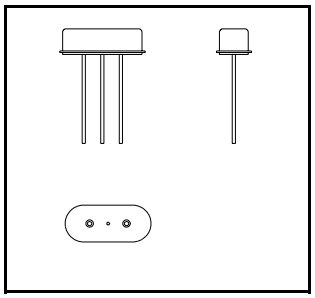
CIRCUIT CALIBRATION CONDITION	FREQUENCY	Holder Type	PART NO.
Parallel Resonance C_L=20pF	20.000000 MHz	HC-49/U-4H	4H200-20
Parallel Resonance C_L=20pF	20.000000 MHz	HC-49/U-4H (3L)	4H200-20 (3L)
Series Resonance=S	20.000000 MHz	HC-49/U-4H	4H200S

*** Note: Calibration tolerance available to ± 2.5 ppm.**
Temperature stability tolerance available to ± 5 ppm.
Pullability spec. available.

HC-49/U-4H(3L)



Enlarged View



Actual Size Shown Above 1=1

HC-49/U-4H Standard Frequencies - TIGHT TOLERANCE - HC-

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
3.000000	030	200
3.276800	032	200
3.579545	035	200
3.600000	036	200
3.634195	0363	200
3.648000	0361	200
3.686400	0368	200
3.840000	038	200
3.932160	039	200
4.000000	040	150
4.032000	0403	150
4.080900	0408	150
4.088000	04088	150
4.096000	0409	150
4.194304	041	150
4.433619	044	150
4.608000	046	150
4.883300	0488	150
4.915200	049	150
5.068800	0506	120
5.120000	051	120
5.669280	056	120
5.990400	059	120
6.000000	060	100
6.144000	061	100
6.250000	062	100
6.500000	065	100
6.553600	0655	100
7.000000	070	80
7.159090	071	80
7.250000	072	80
7.372800	073	80
7.864320	078	80
8.000000	080	80
8.192000	081	80
8.867238	088	80
9.090500	0909	60
9.216000	092	60
9.319060	093	60
9.600000	096	60
9.756000	097	60
9.830400	098	60
10.000000	100	60
10.240000	1024	60
10.730000	1073	60
11.000000	110	60
11.059200	1105	60
11.060000	1106	60
11.080608	1108	60
11.520000	115	60
11.673600	116	60
11.980800	1198	60
11.981350	119	60
12.000000	120	60
12.096000	1209	60
12.288000	122	60
12.800000	128	60
14.000000	140	50

FREQUENCY MHZ	FREQUENCY DESIGNATOR	MAXIMUM EQUIVALENT SERIES RESISTANCE OHMS
14.318180	143	50
14.400000	144	50
14.745600	147	50
15.000000	150	50
15.360000	153	50
15.500000	155	50
15.728640	157	50
16.000000	160	50
16.147200	161	50
16.257000	162	50
16.384000	163	50
16.648258	1664	50
16.800000	168	50
17.100000	171	50
18.000000	180	50
18.432000	184	50
18.867000	188	50
18.869600	1886	50
18.870000	1887	50
19.446800	194	50
19.660800	196	50
19.680000	1968	50
20.000000	200	40
20.300000	203	40
20.500000	205	40
20.700000	207	40
20.800000	208	40
22.118400	221	40
23.040000	2304	40
23.400000	234	40
23.520000	235	40
24.000000	240	40
24.000140	240001	40
24.010000	2401	40
24.080000	2408	40
24.300000	243	40
24.576000	145	40
25.000000	250	40
25.312200	253	40
26.880000	268	40*
28.000000	280	40*
29.000000	290	40*
29.491200	294	40*
30.000000	300	40*
31.350000	313	40*
32.000000	320	40*
32.424000	3242	40*
36.000000	360	40*
40.000000	400	40*
48.000000	480	100 3OT
50.000000	500	100 3OT
57.600000	576	100 3OT
60.000000	600	100 3OT
70.000000	700	100 3OT
75.000000	750	100 3OT
100.000000	1000	100 30T
125.000000	1250	100 30T

*** Fundamental BT-Cut**
Note: Special frequencies and specifications are available upon request.

WTL WORLD TECHNOLOGIES LTD. DATE: _____

QUARTZ CRYSTAL THRU-HOLE/DIP SPECIFICATION RFQ FORM

Supply the Specifications and Fax WTL with your Information

NAME: _____ TITLE: _____ COMPANY: _____

ADDRESS: _____ PHONE: _____ FAX NO: _____

CITY: _____ STATE: _____ ZIP: _____ EMAIL: _____

MAIL STOP: _____

Quantity Needed

IMMEDIATE: _____ DELIVERY REQUIRED: _____

FUTURE NEEDS: _____ APPROX. DELIVERY DATE: _____

CUSTOMER SPEC. DRAWING NO: _____ TARGET PRICE: _____ PER _____

DEVICE TYPE & APPLICATION: _____

PROJECT DESCRIPTION OR NO.: _____

How to Order Custom-Designed WTL Crystals

Please provide the following information concerning your crystal requirements

1. Holder Type _____
2. Nominal Frequency _____MHZ or kHz
3. Frequency calibration tolerance (at+25°C) _____ ppm
4. Load Capacitance (C_L) _____ pf
5. Temperature Stability Tolerance _____ ppm
6. Operating Temperature Range* _____ °C to _____ °C
7. Equivalent Series Resistance (R_S) _____ Ω max.
8. Shunt Capacitance (C_O) _____ pF max.
9. Drive Level (P) _____ mW max.
10. Harmonic Mode _____ Fundamental or _____ Overtone
11. Additional specifications, if any: _____

_____

_____