INTRODUCTION TO CRYSTAL COMPONENTS

GENERAL

Quartz crystals are electro mechanical resonators which are typically used in precision frequency applications such as system clocks, timing circuits, frequency control systems, and local oscillators for data communications systems. To meet frequency control needs, the user has the option of choosing a discrete crystal, with which an oscillator can be built with additional discrete components, or a hybrid crystal oscillator which provides the complete oscillator function in one microminiature package. (See Figure 7-1.)

Discrete crystals are available from 1 kHz to 92 MHz in various package sizes. Over 250 crystal part numbers exist, with up to 100 of them active (consult the listing in Section 7.4). Oscillators built from discrete crystals take up the space of about one 2 × 4 card and use upwards of 20 discrete components.

Hybrid crystal oscillators are available from 900 kHz to 70 MHz with approximately eighty-five released part numbers. The packages are a eight leaded TO-8 can which is 0.650" in diameter and a Dip, 14 pin, 100 mil package. The oscillators require only a 5 Vdc supply and are completely TTL compatible, capable of driving up to 5 TTL loads. ECL compatible oscillators are also available.

The hybrid oscillator offers many advantages over discrete designs. They include:

1. **Size** - The hybrid oscillator occupies less than 1/20 the floor space of discrete design.

2. **Reliability** - The failure rate of the complete hybrid oscillator is 1/2 that of the quartz crystal alone, to which one must add the failure rates of up to twenty additional components and their interconnections.

3. **Performance** - The specified oscillator performance is exactly what the user will see in the application. With the discrete oscillator, the performance is only as good as the oscillator design.

4. **Design Ease** - No design is required with the oscillator.

Advantages of the hybrid crystal oscillator include:

1. Wide frequency range (900 kHz to 70 MHz).

2. Customized to any logic family or power supply requirement.

3. **Cost** - The discrete oscillator is generally thought to be a lower cost than the oscillator. However, the oscillator cost is a total cost whereas the cost of a discrete design is complicated by fluctuating procurement costs, component cost, labor costs, and burden rates associated with oscillator manufacturing. The discrete oscillator may be cheaper, but not by a large amount.

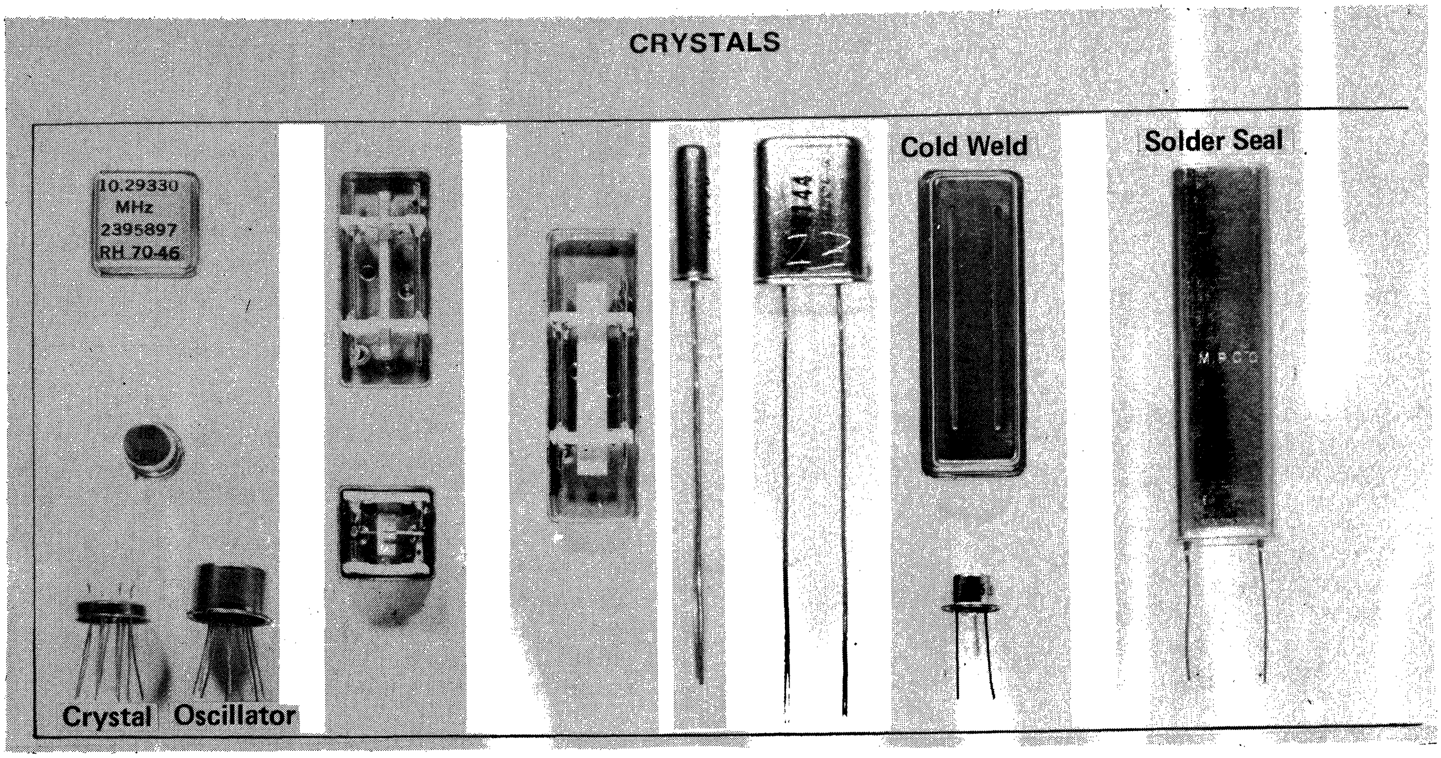


Figure 7-1. Discrete Crystal Product Types Discussed in this Section

QUARTZ CRYSTALS (DISCRETE)

DESCRIPTION

A quartz crystal resonator consists of a finely machined and polished piece of crystalline quartz with two precious metal electrodes (usually gold or silver). The assembly is usually placed in a hermetically sealed metal can with two active leads. An electric potential placed across these leads causes a mechanical deformation of the quartz due to the piezoelectric effect. When subjected to an dc potential, the piezoelectric effect causes the quartz to physically vibrate in its mount. At certain frequencies, determined by the physical dimension and the mass of the quartz, standing waves, similar to acoustic waves, are set up in the quartz blank. At these resonant frequencies, the electrical impedance becomes very low. At all other frequencies, the impedance is ideally very high.

The quartz resonator is often represented as a bandpass filter as shown in Figure 7-2. The component values of the equivalent circuit are related to the physical parameters of the quartz blank as follows:

- Lm - motional inductance
- Cm - motional capacitance
- Rs - series resistance at resonant frequency
- Co - shunt capacitance of holder.

The exact relationships are quite complex and empirically derived.

The frequency performance of a quartz resonator is illustrated by Figure 7-3. Below resonance, the motional capacitance dominates the reactance. At series resonance (fs), Cm, and Lm resonate to give zero reactance. The device impedance is the series resistance of the resonator with 0 degrees phase shift. Above fs, the motional inductance dominates until parallel resonance with Co is reached. At this point, impedance is at a maximum and the phase shifts rapidly from +90° to -90°. This point is termed the anti-resonant frequency fs and fa is inversely proportional to the crystal Q. With few exceptions, crystal performance is specified around its series resonant point. Most oscillators are designed to have the crystal operate with a slightly positive reactance (See Figure 7-3, point X).

The piezoelectric properties of quartz are anisotropic, that is, the effect of applying a voltage will cause an extension or a contraction in a different direction depending on the relative orientation of the crystallographic axis. There is, however, some symmetry. The anisotropy of quartz allows resonators to be designed over a wide range of frequencies (900 kHz to 70 MHz) by changing the angle of the cut. For example, the flexural mode (see Figure 7-4) is used at low frequencies. The frequency determining dimension is length. This mode is relatively insensitive to thickness (except as it relates to mass). A piece of quartz several inches long would be used to provide say a 5 kHz resonator for example. To use the same cut at high frequencies (above 100 kHz) would require extremely short blanks to contain the standing wave. Instead, alternative crystal cuts are used to excite different vibration directions. Figure 7-5 shows the approximate frequency ranges for which the various crystal cuts are useful.

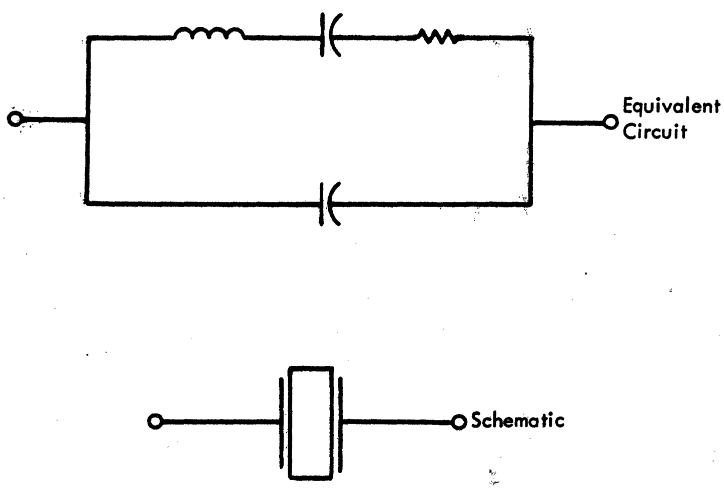


Figure 7-2. Crystal Resonator Equivalent Circuit and Schematic

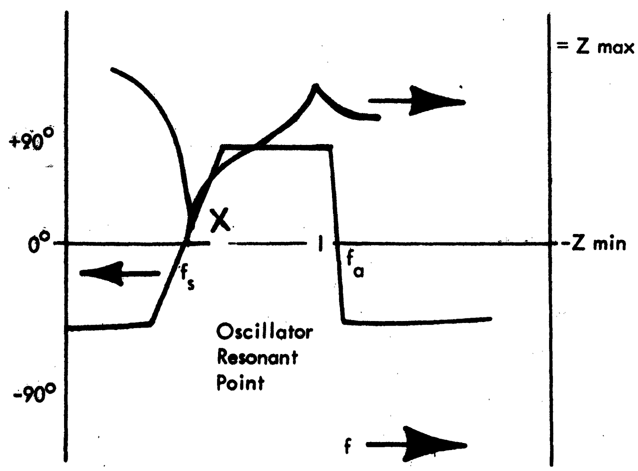


Figure 7-3. Frequency Performance of Crystal Resonator

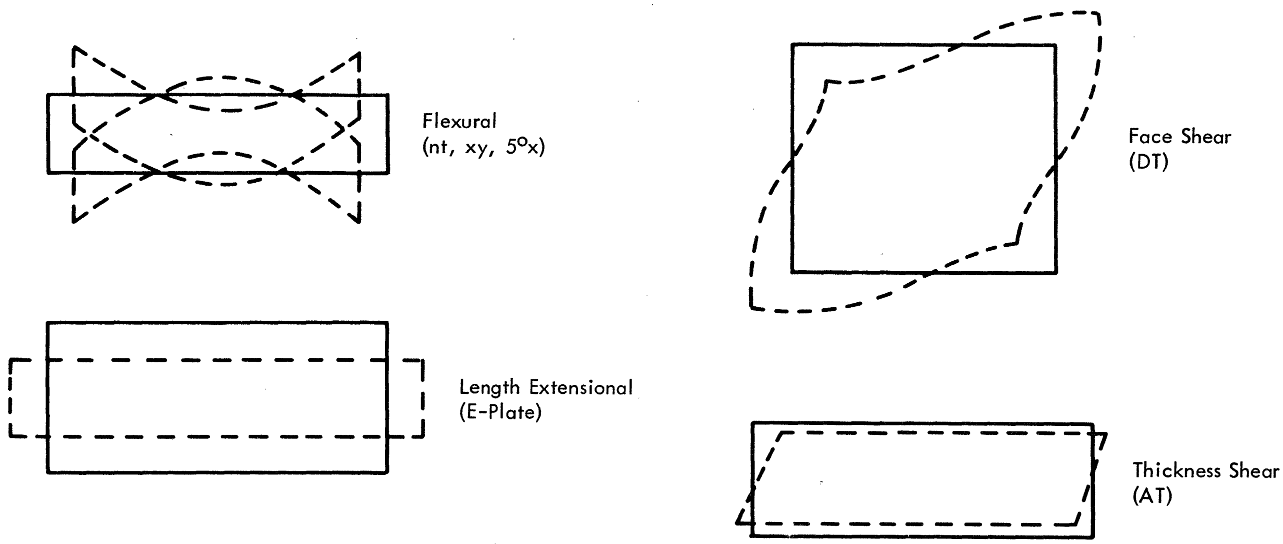


Figure 7-4. Vibration Modes for Various Crystal Cuts

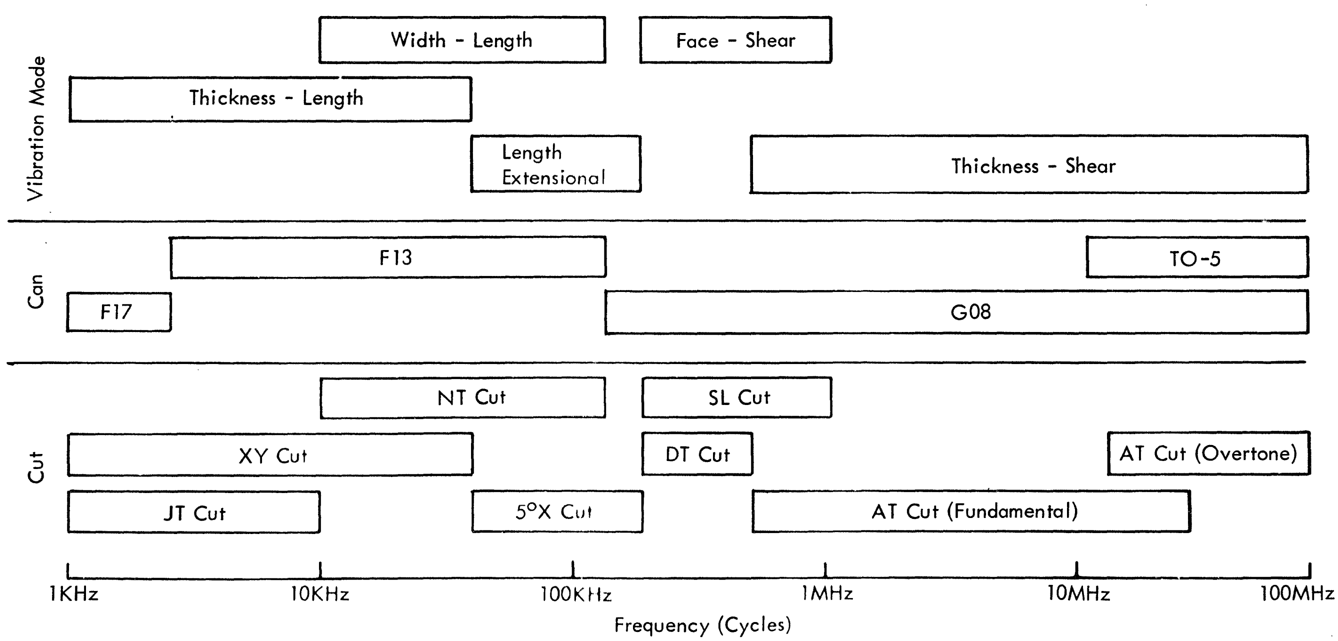


Figure 7-5. Frequency Range Versus Vibration Mode, Package Size, and Cut

The following terms and definitions are useful in understanding quartz resonator performance.

Crystal Blank - the basic crystal slice which has been machined and polished; before the electrodes have been deposited.

Crystal Cut - a term which denotes the angle of the crystal blank with respect to the crystallographic axis.

Series Resonant Frequency (fs) - the frequency at which the motional capacitive reactance equals the motional inductive reactance; the series resonant impedance is at a minimum and the phase change is zero.

Series Resonant Impedance (Rs) - the effective resistance of a crystal operating at its series resonant frequency and specified drive level.

Anti-Resonant Frequency (fa) (parallel resonance) - the frequency at which the total capacitive reactance and the motional inductive reactance are in parallel resonance; the impedance is at a maximum.

Quality Factor (Q) - ratio of stored energy to dissipated energy; the sharpness of the peak at resonance; the slope of the phase versus frequency plot in the area of fs (See Figure 7-3).

Drive Level - the power dissipated by the crystal at series resonant frequency.

Spurious Modes - unwanted oscillations near the resonant frequency but slightly higher; caused by imperfections in the crystal structure, surface defects, mounting effects and edge effects.

AVAILABLE TYPES

Table 7-1 summarizes the range of crystals currently used within IBM and their performance parameters. It represents the practical performance limits of the crystal industry today. Certain parameter performances can be improved upon in special cases (notably frequency tolerance of aging). The AT-cut, by far, represents the most commonly used crystal family.

Figure 7-5 shows the relationship among frequency, crystal cut, case and vibration mode. Figure 7-6 shows the physical outlines of the four crystal cans currently in use.

Figure 7-7A and 7-7B illustrate two typical mounting techniques needed to accommodate the various size crystal blanks.

	Cut	Freq Range	Resistance Range (ohms)	Temp Range	Freq. Tol.	25°C Tol.	Q	Aging (85°C) PPM	Drive Level (Max)	Motional L (Henries)	Motional C (uuf)	Shunt C (uuf)
JT	Special	2K-14KHz	10K-200K	-55°C to 90°C	±.02%	±.0075%	8K-50K	<±40	100μw	5K-250K	.01-.15	5-30
	Special			+10°C to 60°C	±.01%							
	Standard	2K-8.5KHz	20K-150K	+10°C to 60°C	±.025%	±.01%	- - -			- - -	- - -	- - -
XY	Special	2K-50KHz	20K-50K	-55°C to 90°C	±.02%	±.0075%	25-150K	<±30	100μw	2.5K-500K	.003-.035	1-25
	Special			+10°C to 60°C	±.01%							
	Standard	8.5K-16KHz	10K-75K	+10°C to 60°C	±.025%	±.01%	- - -			- - -	- - -	- - -
NT	Special	14K-150KHz	8K-20K	-55°C to 90°C	±.015%	±.005%	30K-50K	<±20	100μw	250-5K	.002-.03	3-15
	Special			+10°C to 60°C	±.0075%							
	Standard	16K-85KHz	10K-75K	+10°C to 60°C	±.025%	±.01%	- - -			- - -	- - -	- - -
5°X	Special	90K-300KHz	1.5K-3K	-55°C to 90°C	±.02%	±.002%	15-50K	<±10	2.0mw	30-100	.005-.05	1.5-7.5
	Special			+10°C to 60°C	±.0075%							
	Standard	85K-210KHz	800-3.5K	+10°C to 60°C	±.01%	±.005%	- - -			- - -	- - -	- - -
DT	Special	200K-500KHz	800-4K	-55°C to 90°C	±.01%	±.0008%	20-50K	<±10	2.0mw	20-40	.003-.03	1-10
	Special			+10°C to 60°C	±.002%							
	Standard	210K-400KHz	800-3.5K	+10°C to 60°C	±.01%	±.005%	- - -			- - -	- - -	- - -
SL	Special	200K-1MHz	500-3K	-55°C to 90°C	±.009%	±.0008%	25-55K	<±10	2.0mw	7-20	.004-.03	1-10
	Special			+10°C to 60°C	±.002%							
	Standard	400K-960KHz	800-3.5K	+10°C to 60°C	±.01%	±.005%	- - -			- - -	- - -	- - -
AT	Special	500K-150MHz	30-1.5K	-55°C to 90°C	±.002%	±.0005%	30-500K	<±10	5.0mw	.01-20	.001-.05	2-15
	Special			+10°C to 60°C	±.001%		- - -			- - -	- - -	- - -
	Standard	0.96M-1.3MHz	70-500	+10°C to 60°C	±.005%	±.002%	- - -			- - -	- - -	- - -
		1.3M-2.0MHz	50-300				- - -			- - -	- - -	- - -
		2.0M-2.5MHz	15-150				- - -			- - -	- - -	- - -
		2.5M-3.6MHz	10-100				- - -			- - -	- - -	- - -
		3.6M-8.0MHz	10-60				- - -			- - -	- - -	- - -
		8.0M-20MHz	3-20				- - -		2.0mw	- - -	- - -	- - -

Table 7-1. Electrical Parameter Capabilities of Crystals

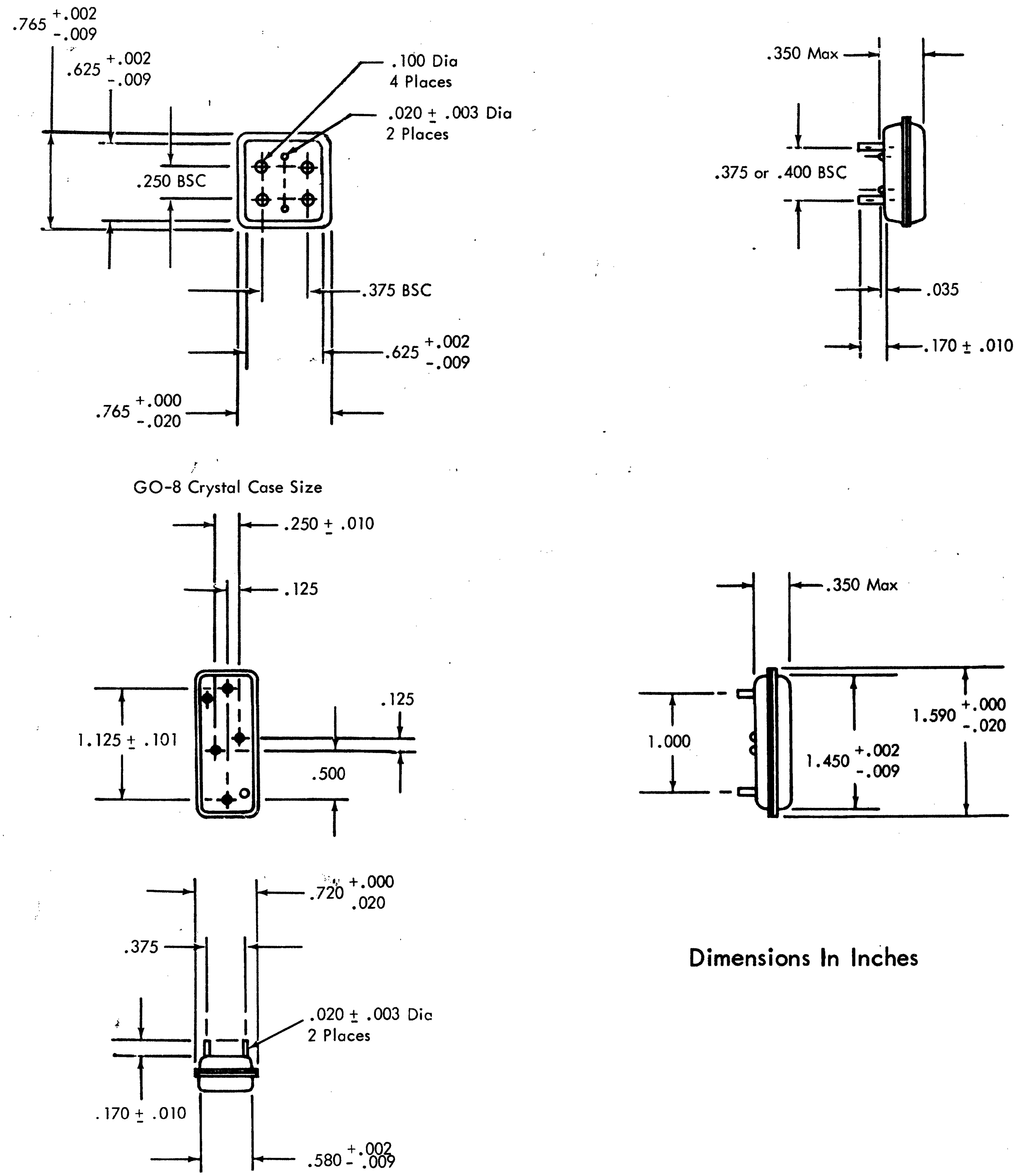


Figure 7-6. Crystal Cases (Part 1 of 3)

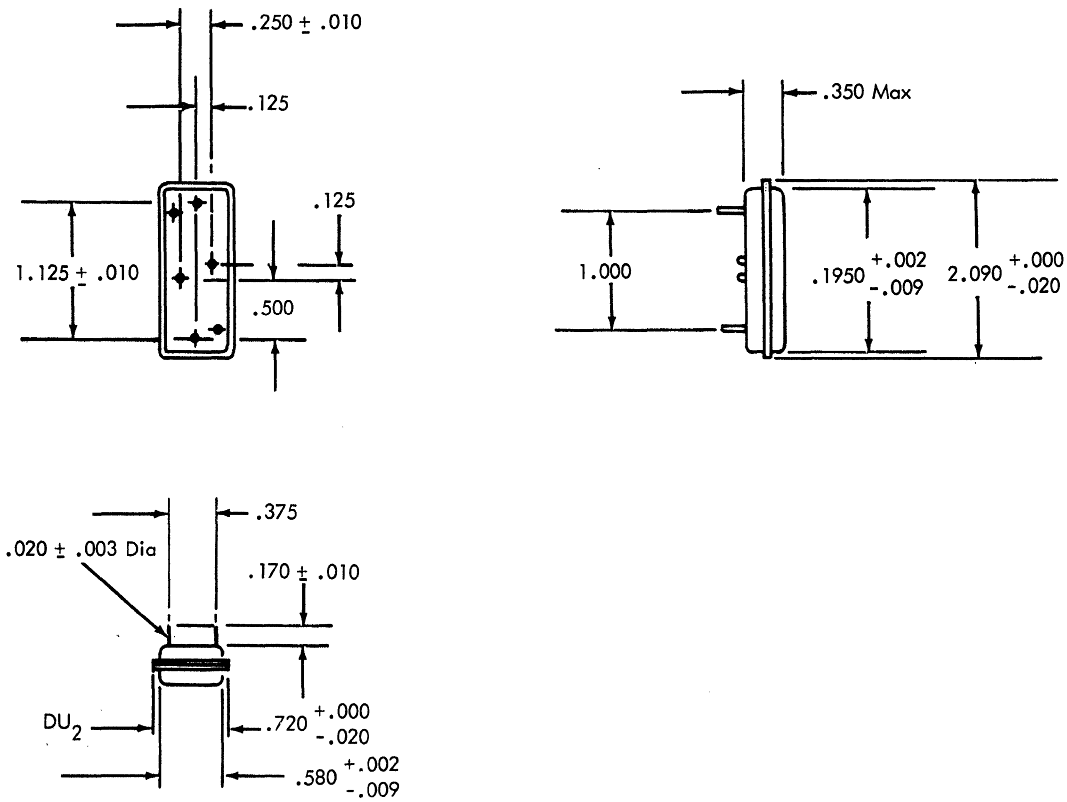
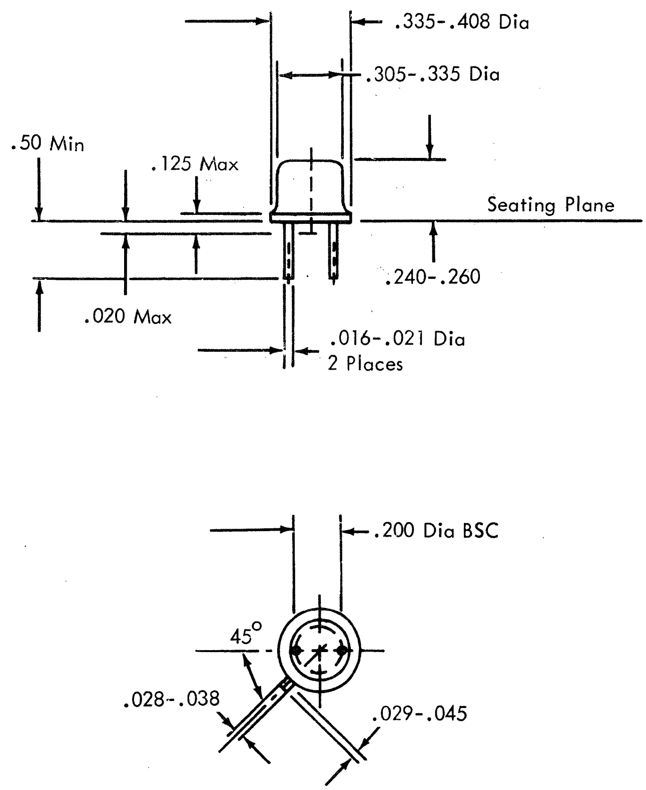


Figure 7-6. Crystal Cases (Part 2 of 3)



Dimensions In Inches

Figure 7-6. Crystal Cases (Part 3 of 3)

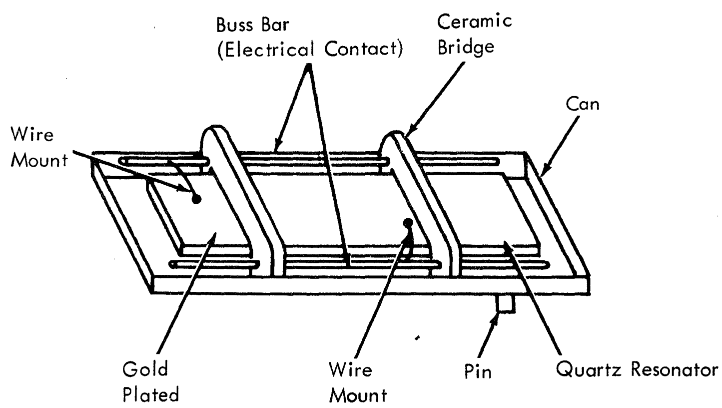


Figure 7-7A. Typical Construction (Non-AT Cut)

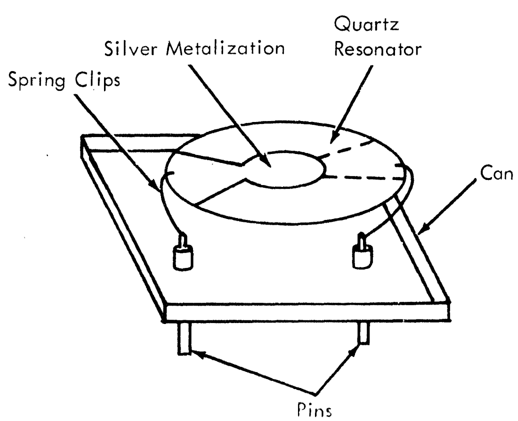


Figure 7-7B. Typical Construction (AT Cut)

PERFORMANCE CHARACTERISTICS

In this section, important resonator performance parameters will be described as they relate to design and processing techniques. Specification of these parameters is required for all crystal resonators. Table 7-1 summarizes the capabilities of the various crystal cuts.

Frequency Performance - the room temperature accuracy capabilities of the various crystal cuts range from ±100 PPM which is standard for AT cut crystals to ±10 PPM obtainable at a higher cost.

Frequency versus Temperature - the AT cut has by far the best frequency versus temperature performance. Figure 7-8 shows the theoretical f versus T performance for AT cut crystals as a function of the crystallographic angle of the crystal blank. Each curve represents a different angle with respect to the ideal AT cut angle of 35°21' away from the crystallographic Z-axis. Note the flat portion of the curve in the usable temperature range of 0°C to 70°C. This in large part accounts for the popularity of the AT cut. Figure 7-9 shows the performance of several other important crystal cuts.

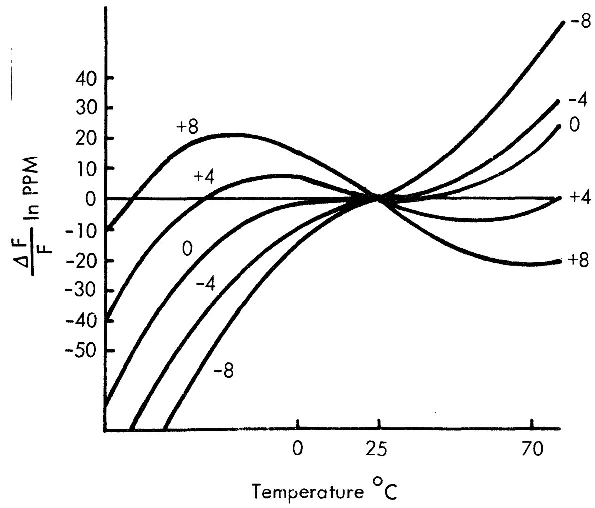
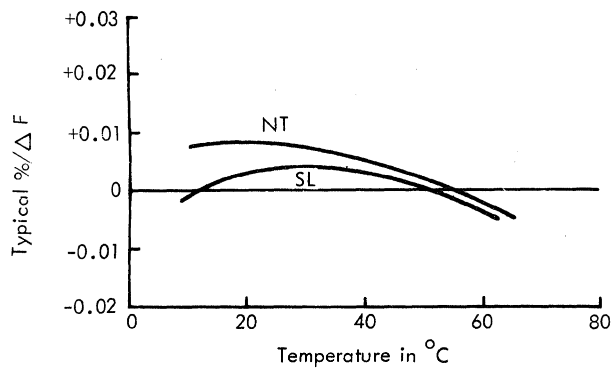


Figure 7-8. Frequency versus Temperature for an AT Cut Crystal (Theoretical)



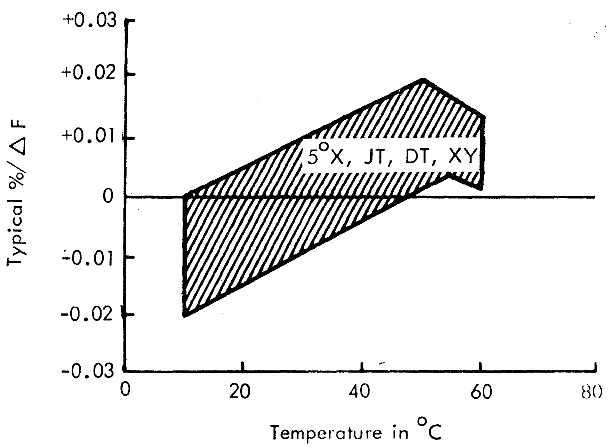


Figure 7-9. Typical Percent Change in Frequency versus Temperature, Non-AT-Cut

Impedance - crystal impedance is related to the amount of energy required to sustain the mechanical vibrations in the quartz blank. The size of the electrode, the crystal finish, mounting resistance, and the atmosphere in the crystal can, all affect the impedance (or "activity") of a crystal.

The electrode size is most often used to adjust the impedance of a given crystal unit. Increasing the size of the electrode activates more of the quartz and generally results in a lower impedance. However, this also decreases the resistance of spurious modes, which increases the probability of "hopping" to an unwanted frequency.

Spurious Modes - "Spurs" are unwanted dips in the impedance of the crystal at frequencies close to, but above, the series resonant frequency. They result from imperfections in the crystal finish (for example, non-parallel surfaces) and edge effects. Spurs are minimized by using smaller electrodes and by contouring one or both crystal surfaces to restrict the pieyoelectric activity to the center of the blank.

Harmonics - most crystal cuts are useful only at the fundamental frequency. The AT cut, will resonate at any frequency for which the thickness is an integral number of wavelengths such that a standing acoustic wave is set up. This happens at the fundamental and at all odd overtones. Oscillator circuits will tend to operate at the lowest frequency at which there is sufficient gain for oscillation. The useful frequency ranges for AT cut crystals are:

fundamental:	550 kHz to 20 MHz
3rd overtone:	10 MHz to 60 MHz
5th overtone:	45 MHz to 125 MHz

The lower frequency limit is due to the large thickness required and the increasing exposure to unwanted modes. The upper limit is due to the difficulty in processing extremely think and fragile blanks.

Overtone crystals generally have a higher impedance but a higher Q than comparable fundamental. They are also more susceptible to spurs. When designing an oscillator with an overtone crystal, a filter must be used to attenuate the fundamental.

Some parameters, less often specified, are:

Q - the quality factor is a measure of the selectivity of the crystal as seen in the phase versus frequency plot of Figure 7-3. The higher Q crystal will have a sharper slope. Q is related to the crystal finish and the thickness of the crystal. In general, Q is inversely proportional to frequency.

Co - shunt capacitance is the capacitance of the crystal measured at some frequency below the fundamental series resonance. It is related to the size of the electrodes and thickness of the crystal.

EOL/Aging

The principal affect of aging in quartz resonators, is a gradual shift in frequency. This results from the relaxations of the strains induced by the machining, plating and mounting of the quartz blank. The rate of aging is at a maximum early in life and generally, but not always, results in decrease in frequency. The rate decreases to a low level that causes shifts in either direction. Short term aging can last up to a year depending on the operating conditions. Long term aging is usually an order of magnitude less than short term aging. Table 7-2 summarizes crystal aging rates for various cuts.

The worst case EOL frequency drift for an AT cut crystal would be the sum of the frequency shift throughout the operating temperature range (±50 PPM) and the five year aging (±36 PPM) or ±86 PPM. Typical EOL performance would be closer to ±40 PPM.

The supported failure rate for quartz crystals is 0.02% per 1k hours with a useful life of 12 years.

Table 7-2. Quartz Crystal Aging Rates by Cut

Cut	1 year Maximum	Typical	5 year (EOL) Maximum	Typical
AT	10	5	36	15
XY,NT, 5°X,SL	13	6	47	20
DT	25	12	90	38
JT	30	14	108	45

DESIGN/APPLICATION CONSIDERATION

Since a quartz resonator is an electro-mechanical vibrator, it is quite sensitive to mechanical and thermal shock. Care should be taken to hand insert all crystals but wave soldering is permissable.

Crystals are quite sensitive to drive level. Increased drive level can greatly accelerate aging. A maximum drive level is specified for each crystal and determines at what level the crystals are measured. It is recommended that crystals be operated at as low a level as is practical.

To minimize the cost of a crystal, potential users should avoid over-specification in the following areas:

- Tighter frequency tolerance than needed.
- Minimum series impedance.
- Low aging requirements.
- Tight frequency versus temperature performance.
- Motional parameters (Capacitance, inductance).

- Q.
- Special packages.

RELIABILITY CONSIDERATIONS

The SPQL for quartz crystals is 700 PPM. There is no ELAL for quartz crystals but crystal lifetime will be increased and failure rate decreased by reducing drive level and/or reducing temperature.

SPECIFICATIONS

The following specifications apply to Quartz Crystals:

Engineering Specifications	- 890754
Quality Specifications	- 873565
	873589
Glass to metal mechanical requirements	- 873522
Glass to metal seal package requirements	- 873523

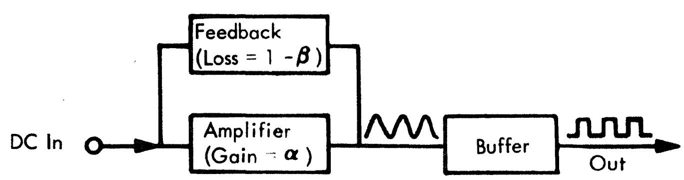
DCS codes: 23751 - Solder Seal Package
23752 - Kold Weld Package
23759 - Special Devices

CRYSTAL OSCILLATORS

DESCRIPTION

The hybrid crystal oscillator provides precise frequency control and TTL compatibility in one miniature, hermetic package. The oscillator and output elements are provided by a thick film hybrid circuit. An AT-cut crystal, similar to those described in the previous crystal section, is suspended over the hybrid substrate by mounting posts. A 5 volt dc source and ground is all that is required for proper operation.

Two major elements are needed to synthesize an oscillator: an amplifier, and a positive feedback loop (see Figure 7-10A). To sustain oscillation, the Barkhausen criteria must be satisfied; that is, the amplifier gain times the transmission coefficient of the feedback loop must be greater than or equal to unity. In addition, the phase shift in the loop must be zero or some internal multiple of 360°. For efficient oscillator operation, the feedback loop should be a low impedance (high transmission coefficient) and should be reactive so as to offset any phase shift in the amplifier section. For stable oscillation, the feedback elements should have a high Q so that, for a slight change in frequency, there is a very large change in impedance and phase angle of the feedback elements. No component or network behaves more suitably for this application that a quartz crystal resonator. Figure 7-10B illustrates a schematic for a typical positive reactance crystal resonator.



Barkhausen Criteria: $\alpha\beta \geq 1$

$\Delta\phi = n360 \qquad n = 0, 1, 2, \ldots$

Figure 7-10A. Block Diagram of Oscillator Which Satisfies Barkhausen Criteria

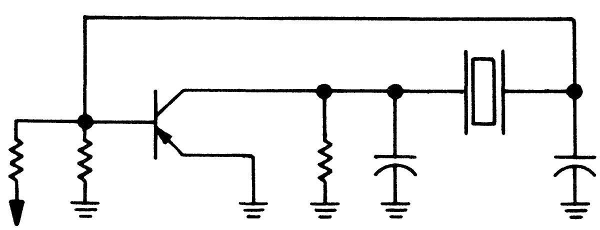


Figure 7-10B. Typical Transistor Sine Wave Oscillator Schematic

The microminiature crystal oscillator provides the elements of a precision crystal-controlled oscillator plus a TTL logic interface in a hermetic package smaller in size than most discrete crystals. Figure 7-11 represents a discrete solid state oscillator, which could have a count of 20 or more discrete components, compared to a single hybrid oscillator. The oscillator has a diameter of 0.650 inches and a height of 0.350 inches.

Figure 7-12 depicts the hybrid substrate, the substrate with the crystal attached, and a completed unit. The substrate supports a thick film hybrid circuit containing an amplifier, voltage dividing networks, and an output buffer for TTL or a frequency divider, which is also TTL compatible. Conventional high performance screened and fired thick film resistor technology is employed with either sand or laser abrades. Ceramic chip capacitors are either reflow attached or epoxy bonded to the lands and conventional die attach and wire bond techniques are used on the semiconductor dice. The crystal blank is epoxy attached to leads suspending it above the hybrid substrate. The assembly is then hermetically sealed in an inert atmosphere. The hermetic environment which is required for the quartz crystal operation substantially improves the reliability expectations of the semiconductors, chip capacitors, and resistors which are conventionally plastic encapsulated.

Figure 7-13 shows the generalized manufacturing sequence.

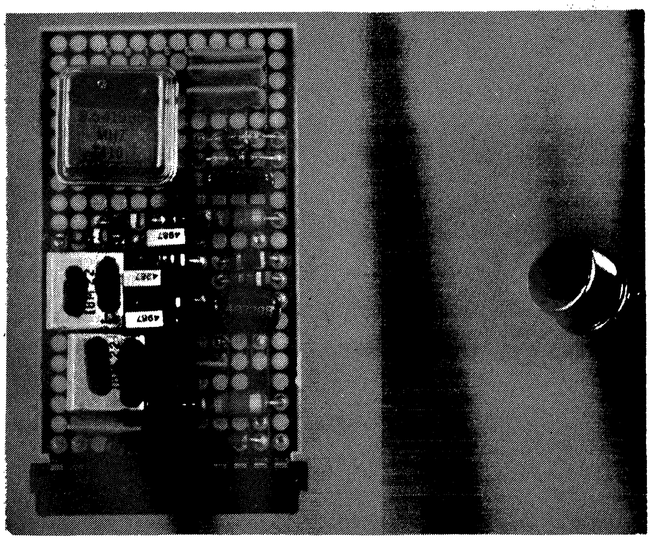


Figure 7-11. Size Relationship Between Printed Circuit Board Layout and Hybrid Package

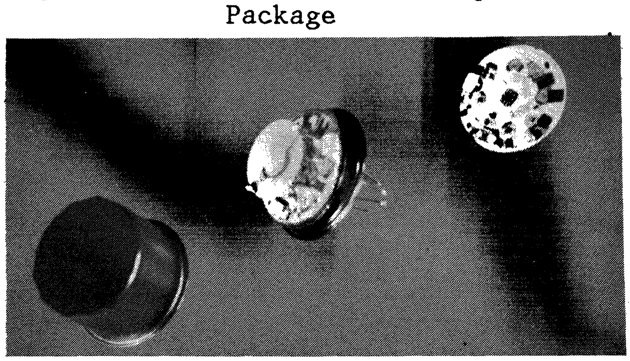


Figure 7-12. Sequence from Substrate to Final Package

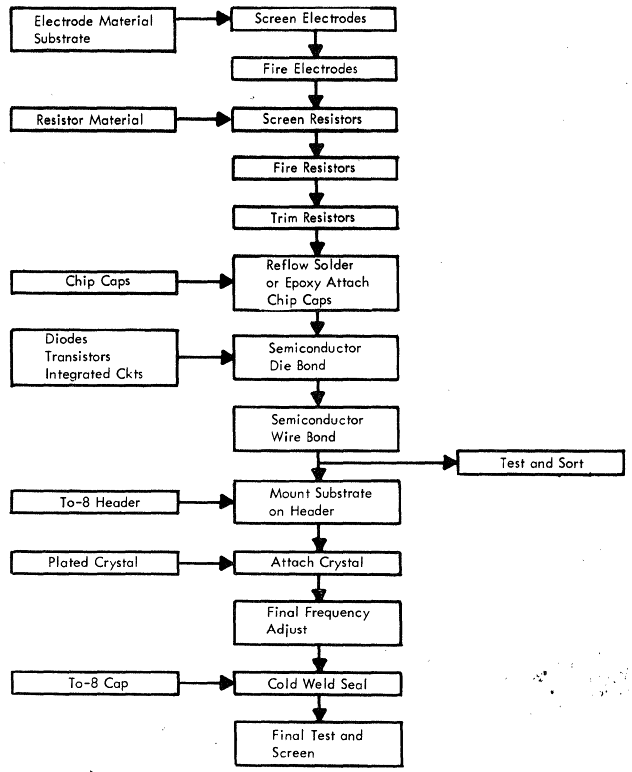


Figure 7-13. Generalized Process Flow Chart for Hybrid Oscillator

AVAILABLE TYPES

Crystal oscillators are currently available in two packages: an eight leaded TO-8 case and a 14 Pin DIP. Figures 7-14A and 7-14B show the physical outlines. Of the eight TO-8 leads, three of four are active depending on number of outputs. Three pins are active on the DIP package with one output active and all four active when a dual output is required.

Currently available frequencies in this package range from 900 kHz to 70 MHz. The upper frequency limit is determined by the difficulty of manufacturing fundamental mode AT cut crystals above 25 MHz, while the lower limit is determined by the maximum allowable size of the AT cut crystal and the number of frequency dividers that will fit in the TO-8 or DIP package. There are, of course, other crystals cuts which allow lower frequencies in even smaller packages, but they cannot match the performance and aging characteristics of the AT cut.

Multiple outputs are available on several part numbers to provide divided frequencies or complementary outputs.

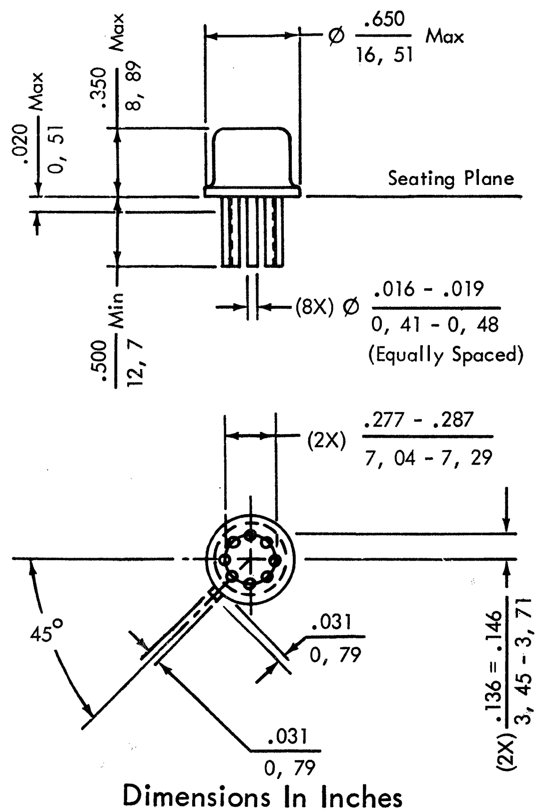


Figure 7-14A. Physical Outline of the TO-8 Can

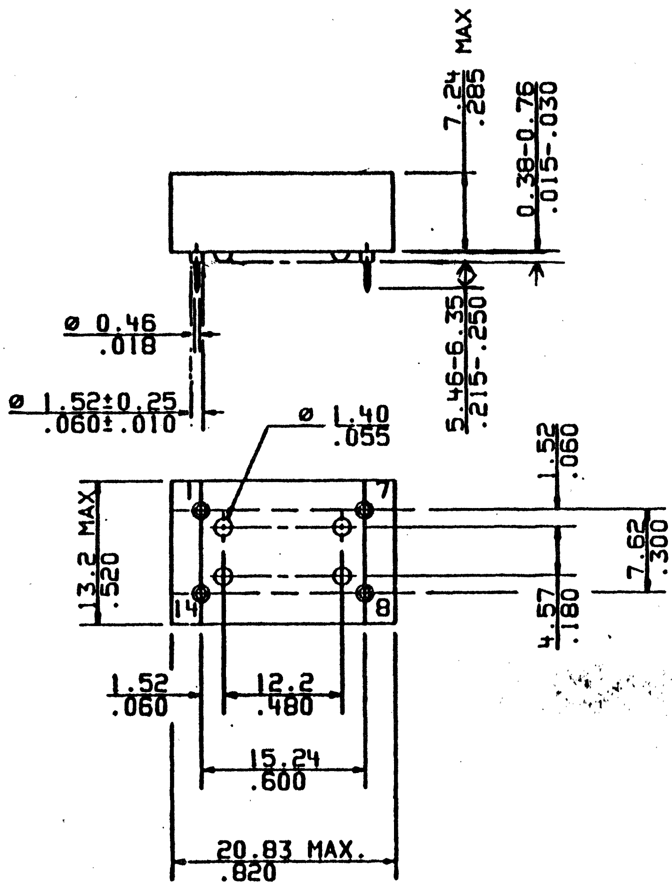


Figure 7-14B. Physical Outline of DIP Packaging

PERFORMANCE CHARACTERISTICS

The frequency performance of the crystal oscillator is dominated by that of the crystal. The frequency tolerance of ±25 PPM at 25°C for the oscillator compares well to that of discrete crystals described in the previous section.

Frequency versus temperature performance is also determined by the basic crystal performance. Figure 7-15 shows the actual performance of two representative devices over the operating range of -10°C to +70°C. Both devices are well within the typical specification tolerance of ±50 PPM over the temperature range and indicate a different cutting angle. These samples represent devices from two different manufacturers. Product from the same manufacturer generally are more tightly distributed with respect to angle and therefore temperature performance.

Although the frequency performance is probably the most important oscillator specification, much more must be said about the digital output than simply that it is TTL compatible. Nominal values and tolerances are assigned to all the waveform parameters and a minimum load is specified. Figure 7-16 is an idealized TTL square wave showing the rise time, symmetry, and logic levels. Rise times are typically 12 to 15 nsec maximum when measured from 0.5 V to 2.4 V on the leading edge. Symmetry is the percent ratio of the up time to the total cycle time as measured at the 1.5 V level, and can range from ±15% to ±5% of the nominal of 50%. At higher frequencies (above 10 MHz) it is more difficult to hold to tighter timing tolerances and it may be required that high speed Schottky devices be employed. It is required that the logic "1" voltage not fall below the 2.4 V least positive up level (LPUL) and that the logic "0" voltage never exceed the 0.5 V Most Positive Down Level (MPDL). These waveform specifications and voltage levels are compatible with those required to drive standard TTL devices available in the semiconductor industry today. They are, however, more explicit and somewhat more conservative than most performance specifications available from TTL suppliers.

Required test circuits and measurement procedures are explicitly specified to minimize correlation difficulties. The measurement circuit specified is equivalent to 10 TTL gates but users are instructed to use no more than a fan-out of 5 inches of their applications.

Dual outputs are available for special applications providing complementary (inverted waveform at the same frequency) and divided frequency (up to +16) outputs. The potential is there for other related outputs which could be exploited if the need arose.

Contrary to previous considerations related to frequency performance, the output waveforms are very sensitive to parametric changes of the hybrid components and to loading also; probably more so than from those of the crystal.

Table 7-3A. A Typical Parametric Ranges of TO-8 Oscillators

Parameter	Values	Tolerances
Frequency	250 kHz to 25 MHz	±0.0025% at 25°C
Temp. vs. frequency	±50 PPM from 10°C to 70°C	Maximum
Rise time	12 nsec to 15 nsec	Maximum
Fall time	12 nsec to 15 nsec	Maximum
Symmetry	50% (skewed waveforms are possible if required)	±5% to ±15%
Logic "1"	2.4 volts	Minimum
Logic "0"	0.5 volts	Maximum

Table 7-3B. Typical Parametric Ranges of DIP Oscillators

Parameter	Values	Tolerances
Frequency	0.9 MHz to 70 MHz	±0.004% at 25°C
Temp. vs. frequency	±50 PPM from 10°C to 70°C	Maximum
Rise time	5 nsec to 18 nsec	Maximum
Fall time	5 nsec to 18 nsec	Maximum
Symmetry	50%	±5% to ±15%
Logic "1"	2.4 volts	Minimum
Logic "0"	0.5 volts	Maximum

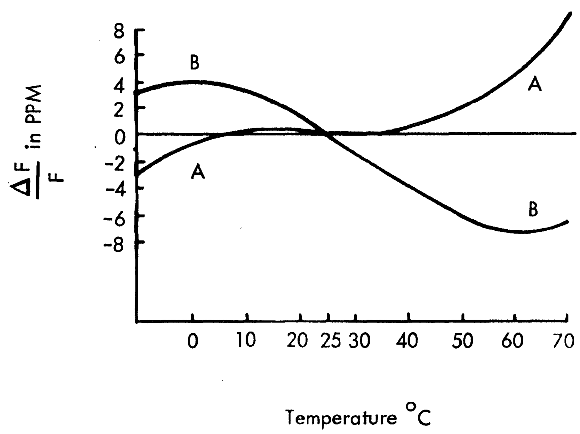


Figure 7-15. Frequency versus Temperature for Hybrid Oscillator (Experimental)

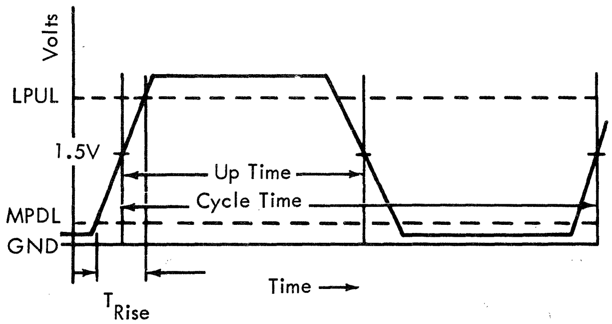


Figure 7-16. TTL Waveform

A major factor contributing to the success of hybrids in general is their proven reliability advantage over comparable discrete designs. The hybrid oscillator is no exception. Besides the mechanical interconnection advantages of the thick film technology, the better part-to-part uniformity of the components in the hybrid design offers tighter control over the drive level of the crystal. The expected aging rate of quartz crystals is directly related to the drive level, all other things being equal. In addition, the integrated output stage, to a large degree, isolates the oscillator from the load. Both factors raise the performance and reliability expectations of the hybrid design.

For any oscillator to demonstrate aging rates similar to discrete crystals would be noteworthy, since the discrete crystals must be subjected to another level of assembly and associated tolerance accumulations and sampling errors before they become functional. Figure 7-17 represents how well the oscillators perform with respect to frequency over extended life. The graph shows the fractional change of frequency exhibited by a group of typical oscillators operating at full load at 85°C for up to 25,000 hours. After an initial decrease in frequency, the rate of aging decreases to a low level with most of the aging occurring in the first 30 days. This performance is typical of AT cut quartz crystals alone. The fact that the aging is negative and is decreasing in rate indicates that a mass sorption mechanism is at work on the crystal. Since the frequency of the crystal is determined by the mass, as well as by the dimensions of the crystal blank, contaminants (water vapor, outgassing) lower the frequency until an equilibrium is reached. After several thousand hours, the aging rate is at a very low level and shows neither positive nor negative tendencies.

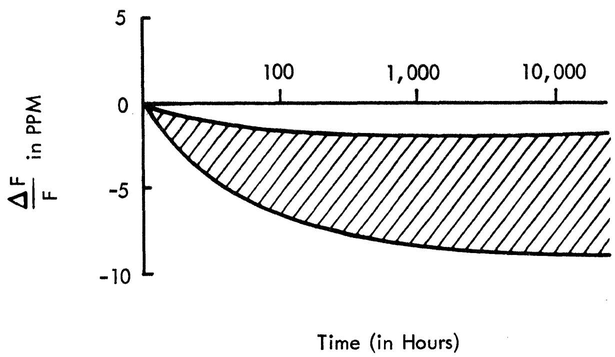


Figure 7-17. Oscillator Aging at 85°C

As stated earlier, the frequency performance is assumed to be a measure primarily of the crystal performance. The waveform parameters of rise time and symmetry, however, which are a direct measure of the hybrid substrate performance, are similarly well behaved over extended life. The rise times and symmetries over the 25,000 hours typically change very little, on the order of 1 nsec, approaching the measurement system accuracy.

The overall failure rate profile could then qualitatively be described as consisting of an early failure mechanism and a long term wear out mechanism of the type normally associated with semiconductors. The profile resembles the classical "bathtub" failure rate curve. The early period is dominated by crystal performance as related to general quality and workmanship (crystal plating, contaminants, lead bonding, hermetic seal). Occurrences of failures of this type peak out relatively early in the component's life. A period of low, relatively stable, failure rates follows. This period is usually termed "useful life". A period of rising failure rates due to wear out can be expected to follow. The wear out mechanism is related to the chemical and mechanical wear out of the semiconductors. The passive thick film elements and the capacitors do not materially contribute to the failure rate.

Although the analysis to date is not rigorous enough to quantitatively determine the failure rate associated with each period, the hybrid oscillator is an extremely reliable component, particularly when compared to the discrete alternatives. The reliability advantage of the hybrid comes primarily from the reduced component count (1 versus ~20), and, therefore, the reduced number of interconnections, and fewer total process steps. There is only one encapsulation process, which is hermetic, required for the quartz whereas in a discrete design a separate encapsulation process with an associated failure rate is needed for each component. The reliability advantage of the hybrid over the discrete version should approach an order of magnitude.

EOL frequency performance is identical to that for AT-cut discrete crystal. Worst case EOL frequency change as a result of temperature and aging should not exceed ±75 PPM and would nominally be closer to ±40 PPM.

The supported failure rate for crystal oscillators 0.01%/1k hours with a useful life of 12 years.

DESIGN/APPLICATION CONSIDERATION

Crystal oscillators in the TO-5 package are very rugged. However, for the quartz crystal to operate properly, a delicate mounting design is necessary. As such, the device is sensitive to mechanical and thermal shock.

The output waveform is sensitive to power supply regulation and loading. Fan-out should be limited to 5 (the fewer, the better) and long lead lengths should be avoided. In all ways, the output should be treated as one would treat the output of any SN74XX gate.

Most of the oscillators draw about 20 mA to 50 mA of dc current at 5 volts. Temperature rise can be from 5°C to 10°C in still air. Short duration voltages of more than 7 volts may destroy the device.

Turn on time for most oscillators is less than 100 msec. For special applications, turn on times of less than 20 msec can be specified. It is recommended however that sufficient time (>200 msec) be allowed for the oscillator to start and demonstrate a stable output.

To minimize the cost of an oscillator, it is recommended that the following be avoided:

1. Overly tight frequency, or frequency versus temperature tolerance.

2. Symmetry tolerance less than ±10%.

3. Frequencies less than 8 MHz or greater than 18 MHz.

4. Dual outputs.

5. Any other non-standard performance parameter.

RELIABILITY CONSIDERATION

The SPQL for crystal oscillator is 1000 PPM. No ELAL failure rate algorithm exists for crystal oscillators but lifetime can be increased and failure rate decreased by reducing the load, temperature, or the number of on/off cycles.

SPECIFICATIONS

The following specifications apply to crystal oscillators:

Engineering Specification	- 865799
Quality Specification	- 866440
	873589
Glass-to-metal Seal Mechanical Requirements	- 873522
Glass-to-metal Seal Package Requirements	- 873523

DCS Codes: 23741 - TTL
23742 - ECL
23749 - Specials

QUARTZ CRYSTALS (DISCRETE)

Component Data Bank - P/N Catalog

DCS CODE
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23751

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PART NUMBER	TUC	FREQUENCY HERTZ	FREQ TOL % 25C	FREQ TOL % 0-60C	DRIVE LEVEL MW	MINIMUM SER-RES OHMS	MAXIMUM SER-RES OHMS	CAN SIZE	CRYSTAL CUT
0483005	C	.0	N.ODATA		.00				
0483010	C	.0	N.ODATA		.00				
0483016	C	.0	N.ODATA		.00				
0483025	C	.0	N.ODATA		.00				
0483027	C	.0	N.ODATA		.00				
0483028	C	.0	N.ODATA		.00				
0483032	C	.0	N.ODATA		.00				
0483053	C	.0	N.ODATA		.00				
0483055	C	.0	N.ODATA		.00				
0483105	C	.0	N.ODATA		.00				
0483132	C	.0	N.ODATA		.00				
0483133	C	.0	N.ODATA		.00				
0483134	C	.0	N.ODATA		.00				
0483139	C	.0	N.ODATA		.00				
0483199	C	.0	N.ODATA		.00				
0483242	C	.0	N.ODATA		.00				
0483243	C	.0	N.ODATA		.00				
0483244	C	.0	N.ODATA		.00				
0483248	C	.0	N.ODATA		.00				
0483250	C	.0	N.ODATA		.00				
0483251	C	.0	N.ODATA		.00				
0483252	C	.0	N.ODATA		.00				
0483267	C	.0			.00				
0483289	C	.0	N.ODATA		.00				
0483291	C	.0	N.ODATA		.00				
0483302	C	.0	N.ODATA		.00				
0483303	C	.0	N.ODATA		.00				
0483312	C	.0	N.ODATA		.00				
0491282	C	.0	N.ODATA		.00				
0492454	C	.0	N.ODATA		.00				
0492519	C	.0	N.ODATA		.00				
0492520	C	.0	N.ODATA		.00				
0492616	C	.0	N.ODATA		.00				
0492671	C	.0	N.ODATA		.00				
0492673	C	.0	N.ODATA		.00				
2391297	C	.0	N.ODATA		.00				
2391308	N	.0	N.ODATA		.00				
2391309	N	.0	N.ODATA		.00				
2391310	N	.0	N.ODATA		.00				
8493531	C	.0			.00				
8493532	C	.0			.00				
0483266	C	1,000.0	.015	.025	.10	50000	100000	SS	JT
2414857	A	2,017.3	.01500	.02500	.10	85000	180000	F13	JT
2414859	A	2,730.6	.01500	.02500	.10	85000	180000	F17	JT
2414821	A	3,000.0	.01000	.02500	.10	30000	100000	F17	JT
2391684	C	3,225.0	.01000	.02500	.10	30000	120000	F13	JT
2414962	A	3,264.8	0.01%	0.025%	.10	30000	120000	F13	JT
2414858	A	3,413.2	.01500	.02500	.10	30000	150000	F13	JT

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2391230	A	3,640.0	.01000	.02500	.15	25000	100000	F13	JT
2391719	A	3,960.0	.01500	.02500	.10	25000	100000	F13	JT
2414963	A	4,004.0	0.01%	0.025%	.10	25000	100000	F13	JT
2391153	A	4,260.0	.01000	.02500	.15	25000	100000	F13	JT
2391253	A	4,304.0	.01000	.02500	.15	25000	100000	F13	JT
2414968	A	4,400.0	0.01%	0.025%	.10	25000	100000	F13	JT
2414860	A	4,452.0	.01000	.02500	.10	25000	75000	F13	JT
2414957	A	4,500.0	0.01%	0.025%	.10	25000	100000	F13	JT
2391265	A	4,600.0	.01000	.02500	.10	25000	100000	F13	JT
2391231	A	4,748.0	.01000	.02500	.15	25000	100000	F13	JT
2391227	A	4,800.0	.01000	.02500	.15	25000	100000	F13	JT
2414964	A	4,840.0	0.01%	0.025%	.10	25000	100000	F13	JT
2414926	A	5,000.0	0.01%	0.025%	.10	20000	75000	F13	JT
2414965	A	5,006.3	0.01%	0.025%	.10	25000	100000	F13	JT
2391229	A	5,824.0	.01000	.02500	.15	25000	100000	F13	JT
2414966	A	5,917.6	0.01%	0.025%	.10	25000	100000	F13	JT
2391226	A	6,400.0	.01000	.02500	.15	25000	100000	F13	JT
2414856	A	6,600.0	0.01%	.02500	.10	25000	75000	F13	JT
2414822	A	6,670.0	.01000	.02500	.10	25000	75000	F13	JT
2391111	A	6,750.0	.01000	.02500	.10	25000	75000	F13	JT
2391228	A	7,040.0	.01000	.02500	.15	25000	100000	F13	JT
2391770	A	7,200.0	.01000	.02500	.10	20000	70000	F13	JT
2391817	A	7,680.0	.02000	.02000	.10	20000	75000	F13	JT
2391769	A	8,069.4	.01500	.02500	.10	20000	75000	F13	JT
2391900	N	8,608.0	.01000	.02500	.15	25000	75000	F13	XY
2414882	A	8,880.0	.01000	.02500	.10	20000	70000	F13	XY
2391742	A	8,928.0	.	.	.10	20000	70000	F13	JT
2391281	A	9,387.0	.01500	.02500	.10	20000	70000	G08	JT
2414820	A	9,600.0	.01000	.02500	.15	20000	70000	F13	XY
2414823	A	10,000.0	.00800	.01000	.10	15000	60000	F13	XY
2391320	A	10,450.0	.01000	.02500	.10	15000	60000	F13	XY
2414881	A	10,800.0	.01000	.02500	.10	15000	60000	F13	XY
2391677	C	11,550.0	.01500	.02500	.10	15000	60000	F13	XY
2391273	A	12,243.0	.01000	.02500	.10	15000	60000	F13	XY
2391771	A	12,498.0	.01000	.02500	.10	15000	60000	F13	XY
2391045	A	15,059.0	.02500	.05000	.50	15000	50000	F13	XY
2391264	A	15,200.0	.01000	.02500	.10	15000	50000	F13	XY
2391028	A	15,750.0	.01000	.02500	.10	15000	60000	F13	XY
2391216	A	16,800.0	.01000	.02500	.10	15000	60000	F13	NT
2391202	A	18,000.0	.01000	.02500	.10	25000	75000	F13	NT
2391225	A	19,200.0	.01000	.02500	.20	25000	75000	F13	NT
2410078	A	28,500.0	.00800	.01000	.10	25000	75000	F13	NT
2391209	A	30,000.0	.00800	.01000	.10	25000	75000	F13	NT
2391289	A	30,400.0	.00800	.01000	.10	20000	60000	F13	NT
5616989	A	36,000.0	.008%	.01%	.10	25000	75000	F13	NT
2391802	A	40,200.0	.00800	.01000	.10	10000	35000	F13	NT
2414876	A	40,800.0	.00800	.01000	.10	10000	35000	F13	NT
2414824	A	51,200.0	.00800	.01000	.10	10000	35000	F13	NT

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2391692	A	52,800.0	.00800	.01000	.10	10000	35000	F13	NT
2391026	A	67,200.0	.00200	.00200	2.00	1200	2000	F13	NT
2396554	C	67,200.0	.00800	.01000	.10	10000	60000	F13	NT
2414819	A	76,800.0	.	.00200	2.00	1200	2000	F17	NT
2414826	A	76,800.0	.	.00200	2.00	1000	450	F13	NT
0483314	C	81,600.0	0.002	0.003	2.00		600	SS	NT
2391217	A	81,600.0	.00500	.01000	.10	20000	60000	F13	NT
1582660	C	86,400.0	0.002	0.004	2.00	1000	3500	F13	DT
2414827	A	96,000.0	.00200	.00400	2.00	1000	3500	F13	NT
2414828	A	100,000.0	.00500	.01000	2.00	1000	3500	F13	5X
2414829	A	115,000.0	.01000	.02000	2.00	1000	3500	F13	5X
2391983	A	115,200.0	.00200	.00200	2.00	1000	3500	F13	5X
2396825	A	121,600.0	.00150	.00500	.00	800	3500	F13	5X
0483315	C	128,000.0	.002	.002	2.00		600	SS	5X
2391206	A	128,000.0	.00150	.00200	.00	800	3500	G08	5X
2414830	A	128,000.0	.00200	.00400	2.00	1000	3500	F13	5X
2391213	A	150,000.0	.01000	.02000	2.00	850	3000	F13	5X
2391180	A	153,600.0	.00150	.00500	.00	1000	3500	G08	5X
2414831	A	160,000.0	.01000	.02000	2.00	850	3000	F13	5X
2391656	C	180,000.0	.05000	.07000	2.00	800	3500	SS	5X
2391318	A	192,000.0	.00800	.01000	2.00	1000	3000	F13	5X
2391149	A	200,000.0	.00800	.01000	2.00	1000	3000	G08	5X
2391278	A	225,000.0	.00800	.01000	2.00	1000	3000	G08	DT
2391820	A	230,400.0	.00800	.01000	2.00	1000	3000	G08	DT
2414832	A	240,000.0	.00800	.01000	2.00	1000	3000	G08	DT
2410131	C	262,144.0	.00800	.01000	2.00	1000	5000	G08	DT
2414833	A	265,000.0	.00800	.01000	2.00	1000	3500	G08	DT
2391686	C	307,200.0	.00150	.00250	.10	1000	3000	G08	DT
2414834	A	320,000.0	.00500	.01000	2.00	1000	3000	G08	DT
2391105	A	333,500.0	.00500	.01000	2.00	800	3000	G08	DT
2414960	A	340,000.0	0.005%	0.01%	2.00	1000	3000	G08	DT
2414835	A	347,500.0	.00800	.01000	2.00	1200	5000	G08	DT
2414836	A	360,000.0	.00800	.01000	2.00	1200	5000	G08	DT
2391031	A	384,000.0	.00150	.00250	.00	1500	3500	F13	DT
2391807	A	403,200.0	.00150	.00250	.00	1500	3500	G08	DT
2391016	A	415,000.0	.00800	.01000	2.00	1000	3000	G08	SL
2392059	A	475,000.0	.00500	.01000	2.00	800	3000	G08	SL
2391106	A	480,000.0	.00800	.01000	2.00	800	3000	G08	SL
2414915	A	500,000.0	0.008%	0.01%	2.00	800	3000	G08	SL
2391296	A	512,000.0	.00100	.00200	.50	800	3500	G08	SL
2391017	A	540,000.0	.00800	.01000	2.00	850	3000	G08	SL
2396645	A	620,544.0	.00500	.01000	2.00	800	3500	F13	SL
2414837	A	625,000.0	.00800	.01000	2.00	800	3000	G08	SL
2414838	A	667,000.0	.00800	.01000	2.00	800	3000	G08	SL
2414839	A	720,000.0	.00800	.01000	2.00	800	3000	G08	SL
2396646	A	734,424.0	.00500	.01000	2.00	800	3500	F13	SL
2391827	A	774,000.0	.00100	.00300	2.00	1000	3500	G08	SL
2392062	A	864,000.0	.00200	.00300	2.00	1000	3500	G08	SL

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2414840	C	960,000.0	.00200	.00500	10.00	100	500	G08	AT
2391862	C	979,200.0	.00200	.00500	5.00	90	500	G08	AT
2391169	C	1,000,000.0	.00100	.00200	5.00	70	450	G08	AT
2414841	C	1,000,000.0	.00200	.00500	10.00	90	450	G08	AT
2395899	A	1,152,000.0	.00200	.00500	5.00	90	450	G08	AT
2391302	C	1,228,800.0	.00150	.00200	5.00	70	400	G08	AT
2414842	C	1,330,000.0	.00200	.00500	10.00	60	300	G08	AT
2414955	C	1,360,000.0	0.002%	0.005%	2.00	50	300	G08	AT
2414914	A	1,399,000.0	0.002%	0.004%	10.00	50	300	G08	AT
2414843	C	1,440,000.0	.00200	.00500	10.00	50	250	G08	AT
2414956	C	1,496,000.0	0.002%	0.005%	2.00	50	300	G08	AT
2414844	A	1,500,000.0	.00200	.00500	10.00	50	300	G08	AT
2396806	A	1,638,400.0	.00200	.00500	5.00	50	300	G08	AT
2391012	A	1,667,000.0	.00300	.00500	5.00	50	300	G08	AT
2396566	A	1,708,000.0	.00200	.00500	5.00	50	300	G08	AT
2391141	A	1,750,000.0	.00200	.00500	5.00	50	300	G08	AT
2396893	A	1,875,000.0	.00200	.00500	5.00	50	300	G08	AT
2395866	A	1,920,000.0	.00200	.00500	5.00	50	300	G08	AT
2414850	A	2,000,000.0	.00150	.00200	10.00	30	150	G08	AT
4481582	C	2,048,000.0	0.0025%	0.005%	5.00	200	8	G08	AT
2391662	A	2,222,000.0	.00150	.00250	10.00	15	100	G08	AT
2414845	A	2,250,000.0	.00200	.00500	10.00	15	100	G08	AT
2414846	A	2,400,000.0	.00200	.00500	10.00	15	100	G08	AT
2414855	A	2,500,000.0	.00300	.00500	10.00	15	90	G08	AT
2391301	A	2,560,000.0	.00300	.00500	5.00	15	90	G08	AT
2391930	A	2,592,000.0	.00300	.00500	5.00	10	100	G08	AT
2391198	A	2,780,000.0	.00200	.00500	5.00	15	100	G08	AT
2391282	A	2,880,000.0	.00300	.00500	5.00	15	90	G08	AT
2391020	A	3,000,000.0	.00300	.00500	5.00	25	120	G08	AT
2391803	C	3,088,000.0		.001	.10	7	20	SPE	AT
2391721	A	3,177,000.0	.00200	.00500	5.00	10	100	G08	AT
2395865	A	3,200,000.0	.00200	.00500	5.00	10	100	G08	AT
2414937	A	3,200,000.0	0.003%	0.005%	5.00	10	105	G08	AT
2391886	C	3,333,300.0	.002	.005	2.00	10	35	G08	AT
2391884	A	3,571,000.0	.	.00250	5.00	10	30	G08	AT
2391315	A	3,600,000.0	.00200	.00500	5.00	10	100	G08	AT
2391284	A	3,640,000.0	.00300	.00500	5.00	10	60	G08	AT
2391168	C	3,962,800.0	.00100	.	5.00	10	60	G08	AT
2414925	A	4,000,000.0		0.0025%	5.00	10	30	G08	AT
5615940	C	4,000,000.0	0.0015%	0.0025%	5.00	10	30	G08	AT
8519384	C	4,000,000.0		0.015%	5.00	10	50	VM1	AT
2396525	A	4,001,800.0	.	.00100	5.00	10	30	G08	AT
2396818	A	4,069,000.0	.00200	.00500	5.00	10	60	G08	AT
8519385	C	4,915,200.0		0.015%	5.00	10	50	VM1	AT
4429704	C	4,976,640.0		0.01%	2.00		75	VM1	AT
2391178	A	5,000,000.0	.00200	.00500	5.00	10	50	G08	AT
2391205	A	5,340,000.0	.00200	.00500	5.00	10	50	G08	AT
2414866	A	5,710,000.0	.00200	.00500	5.00	10	50	G08	AT

PG. 5 06/30/82 23:36 UR0206 *** IBM INTERNAL USE *** COMPONENT DATA BANK INTERNAL USE ONLY
CDB/QC ALL/QC TECH QC/PAR1 SEQ/LH QC/FREQ/HZ NO/LIMIT.

PART NUMBER	TUC	FREQUENCY HERTZ	FREQ TOL % 25C	FREQ TOL % 0-60C	DRIVE LEVEL MW	MINIMUM SER-RES OHMS	MAXIMUM SER-RES OHMS	CAN SIZE	CRYSTAL CUT
8493146	A	5,760,000.0	.002%	.005%	5.00	10	50	G08	AT
2414847	A	6,000,000.0	.00200	.00500	5.00	10	30	G08	AT
8493175	C	6,000,000.0		.10%	10.00	8	70	G08	AT
8493283	C	6,000,000.0	.02%	.04%	2.00	10	35	VM1	AT
8493590	C	6,000,000.0		0.1%	10.00	8	70		AT
4430094	A	6,144,000.0		0.01%	5.00	10	60	G08	AT
8493580	C	6,144,000.0		0.01%	10.00	10	70		AT
2396608	A	6,250,000.0	.00150	.00200	5.00	10	40	G08	AT
2414933	A	6,250,000.0	0.002%	0.005%	10.00	10	30	G08	AT
2396604	A	6,666,700.0	.00150	.00200	5.00	10	40	G08	AT
2396817	A	6,781,000.0	.00200	.00500	5.00	10	20	G08	AT
2410112	C	7,052,500.0	.00150	.00250	2.00	10	35	G08	AT
2396719	A	7,098,000.0	.00150	.00250	2.00	10	35	G08	AT
2396553	A	7,159,090.0	.00150	.00250	2.00	10	35	G08	AT
2396612	A	7,372,800.0	.00200	.00500	5.00	10	60	G08	AT
1582837	C	7,500,000.0	0.002	0.002	1.00	10	35	G08	AT
8519690	C	7,500,000.0		0.015%	2.00		35	YM1	AT
2391029	A	8,000,000.0	.00150	.00250	5.00	5	20	G08	AT
4429951	C	8,000,000.0	0.005%	0.01%	2.00		35	VM1	AT
8272238	A	8,000,000.0	.0015%	.0025%	5.00	10	50	T05	AT
2391800	A	8,192,000.0	.00100	.00100	5.00	5	20	G08	AT
2391895	A	8,300,000.0	.00200	.00500	2.00	3	20	G08	AT
2396605	A	8,670,000.0	.00200	.00500	5.00	3	20	G08	AT
2396621	A	9,000,000.0	.00200	.00500	5.00	3	20	G08	AT
2392091	A	9,541,900.0	.00200	.00500	5.00	3	20	G08	AT
1582537	A	9,600,000.0	0.002	0.005	5.00	3	20	G08	AT
2396814	C	9,830,400.0	.002	.005	2.00	3	20	G08	AT
2414958	A	10,000,000.0	0.0015%	0.0025%	5.00	3	20	G08	AT
5615941	C	10,000,000.0	0.0015%	0.0025%	5.00	3	35	T05	AT
2391186	A	10,256,000.0	.00150	.00250	5.00	3	20	G08	AT
2395897	A	10,293,300.0	.00100	.00100	5.00	3	20	G08	AT
2391127	A	10,526,000.0	.00150	.00250	5.00	3	20	G08	AT
2396816	A	10,850,000.0	.00200	.00500	2.00	3	20	G08	AT
2391350	A	11,120,000.0	.00200	.00500	2.00	3	20	G08	AT
2395805	A	11,430,000.0	.00150	.00250	5.00	3	20	G08	AT
5615942	C	11,430,000.0	0.0015%	0.0025%	5.00	3	35	T05	AT
2396602	A	11,600,000.0	.00200	.00500	5.00	20	3	G08	AT
1585991	A	11,700,000.0	0.002	0.005	5.00	3	20	G08	AT
2396535	A	11,796,000.0	.00200	.00500	5.00	3	20	G08	AT
2391744	A	12,127,000.0	.00200	.00500	2.00	3	20	G08	AT
4430017	C	12,288,000.0	0.005%	0.01%	2.00		50	VM1	AT
4430035	A	12,500,000.0	0.0015%	0.0025%	5.00	10	50	T05	AT
2396622	A	12,600,000.0	.00200	.00500	5.00	10	60	G08	AT
2396899	A	13,333,300.0	.00150	.00250	2.00	3	20	G08	AT
5615982	C	13,333,300.0	0.0015%	0.0025%	5.00	3	20	T05	AT
2396460	A	13,900,000.0	.00200	.00500	5.00	3	20	G08	AT
2396482	A	13,900,000.0	.00200	.00500	2.00	3	20	T05	AT
1589329	A	14,049,600.0	.002	.005	5.00	3	20	G08	AT

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CDB/QC ALL/QC TECH QC/PAR1 SEQ/LH QC/FREQ/HZ NO/LIMIT.

PART NUMBER	TUC	FREQUENCY HERTZ	FREQ TOL % 25C	FREQ TOL % 0-60C	DRIVE LEVEL MW	MINIMUM SER-RES OHMS	MAXIMUM SER-RES OHMS	CAN SIZE	CRYSTAL CUT
1589449	A	14,152,300.0	0.002	0.005	5.00	3	20	G08	AT
8493147	C	14,745,600.0	.002%	.005%	5.00	3	25	G08	AT
5617824	A	15,000,000.0	0.002%	0.005%	5.00		25	G08	AT
1589330	A	16,000,000.0	.002	.005	5.00	3	20	G08	AT
2391878	A	16,000,000.0	.00200	.00500	5.00	3	20	G08	AT
4430036	A	16,666,600.0	0.0015%	0.0025%	5.00	5	30	T05	AT
4718633	A	17,391,300.0	0.0015%	0.0025%	5.00	5	30	T05	AT
2391317	A	17,600,000.0	.00300	.00500	5.00	3	15	G08	AT
8272124	A	17,777,800.0	0.002%	0.005%	5.00	3	20	G08	AT
2396785	A	18,000,000.0	.00200	.00500	2.00	3	20	G08	AT
2391877	A	18,182,000.0	.00800	.01000	2.00	8	35	G08	AT
2396820	A	18,750,000.0	.00100	.00200	2.00	10	40	T05	AT
4429948	C	18,870,000.0	0.01%	0.01%	2.00		50	VM1	AT
2396607	A	19,084,000.0	.00200	.00500	2.00	8	35	G08	AT
2396966	A	19,910,000.0	.00100	.00250	2.00	10	35	G08	AT
2391366	A	20,000,000.0	0.00200	0.00500	2.00	5	35	G08	AT
5617805	A	20,000,000.0	0.002%	0.005%	2.00	5	35	G08	AT
8493389	C	20,000,000.0		0.005%	5.00		25	G08	AT
4429701	A	20,007,000.0		0.025%	2.00	3	35	T05	AT
2395857	A	20,480,000.0	.00200	.00500	2.00	5	35	G08	AT
2391290	A	21,360,000.0	.00200	.00500	2.00	8	35	G08	AT
2396606	A	22,220,000.0	.00200	.00500	2.00	8	35	G08	AT
2391732	A	22,222,000.0	.00200	.00500	2.00	10	35	G08	AT
8493501	C	24,000,000.0	0.01%	0.01%	2.00	5	75		AT
4430065	C	24,008,000.0		0.0025%	2.00	10	20	G08	AT
4481617	C	24,700,000.0	0.01%	0.01%	2.00	35	105	VM1	AT
2391305	C	25,000,000.0	.00200	.00500	2.00	10	35	G08	AT
4429652	C	26,667,600.0		0.025%	2.00	10	20	G08	AT
8519280	C	28,262,400.0	0.005%	0.005%	2.00	5	40	T05	AT
1589448	A	30,000,000.0	0.002	0.005	2.00	10	35	G08	AT
5617109	A	31,000,000.0	0.002%	0.005%	2.00		35	G08	AT
8519390	C	32,000,000.0	0.05%	0.05%	2.00	5	40	VMI	AT
6833146	C	32,005,000.0		.0025%	2.00	10	20	G08	AT
2391330	A	34,783,000.0	.00200	.00500	2.00	10	35	G08	AT
5615453	A	35,088,000.0	0.002%	0.005%	2.00	10	35	G08	AT
5616793	C	35,091,000.0		0.0025%	2.00	10	20	T08	AT
1582559	C	36,363,000.0	.00200	.00500	2.00	10	35	G08	AT
5615694	C	40,000,200.0		0.0010%	2.00		25	G08	AT
2391344	A	41,700,000.0	.00200	.00500	2.00	8	35	G08	AT
8493266	C	42,456,900.0		.005%	2.00	8	35	G08	AT
2391151	C	50,000,000.0	.00200	.00500	2.00	10	35	G08	AT
8279295	A	50,000,000.0	.0015%	.0025%	2.00	10	40	T05	AT
8519150	C	50,000,000.0	0.01%	0.01%	.00	5	75	VMI	AT
8493813	A	52,631,000.0	0.002%	0.0025%	2.00	10	40	T05	AT
8279296	A	53,333,200.0	.0015%	.0025%	2.00	10	40	T05	AT
2396552	C	55,250,000.0	.00150	.00250	2.00	10	35	T05	AT
8493812	A	58,823,000.0	0.002%	0.0025%	2.00	10	40	T05	AT
4481486	A	60,000,000.0	0.002%	0.005%	2.00	10	60	T05	AT
2395858	C	61,250,000.0	.00200	.00500	2.00	10	60	G08	AT
2396674	C	61,250,000.0	.00150	.00250	2.00	10	60	T05	AT
8493811	A	62,500,000.0	0.002%	0.0025%	2.00	10	40	T05	AT
8279297	A	66,666,400.0	.0015%	.0025%	2.00	10	40	T05	AT
2395859	C	67,250,000.0	.	.	2.00	10	60	G08	JT
2397095	C	80,000,000.0	.00100	.00200	2.00	10	50	G08	AT
2391898	C	92,579,000.0	.00200	.00500	2.00	10	60	T05	AT
4481616	B	100,000,000.0	0.01%	0.01%	1.00		60	T05	AT

TOTAL RECORDS 296

CRYSTAL OSCILLATORS

Component Data Bank - P/N Catalog

DCS CODE
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PG. 1 06/30/82 23:36 UR0206 *** IBM INTERNAL USE *** COMPONENT DATA BANK INTERNAL USE ONLY
CDB/OSC ALL/OSC TECH OSC/PAR1 SEQ/LH OSC/FREQ/HZ1 NO/LIMIT.

PART NUMBER	T U C	FIRST O/P FREQUENCY HERTZ	SECOND O/P FREQUENCY HERTZ	SYM- METRY %	FREQ. TOL. % 25 DEG C	FREQ. TOL. % 0TO70	FAM- ILY	TECH- NOLOGY	INPUT VOLTAGE +-10%	MAXIMUM CAP.LD. P.F.	CAN SIZE
1582849	L	.00	NO DATA	.00					.00	.00	
1582994	L	.00	NO DATA	.00					.00	.00	
1582995	L	.00	NO DATA	.00					.00	.00	
1582996	L	.00	NO DATA	.00					.00	.00	
1589258	L	.00	NO DATA	.00					.00	.00	
4429964	E	.00	NO DATA	.00					.00	.00	
1582718	E	900,800.00		10.00	.004%	.006%	1	TTL	5.00	35.00	TO-8
8493422	C	900,800.00		10.00	.01%	.01%		TTL	5.00	35.00	DIP
8493243	C	1,302,500.00		10.00	.1%	.1%	9	TTL	5.00	35.00	DIP
8493514	C	2,097,152.00		10.00	.025%	.035%		TTL	5.00	35.00	DIP
8493201	C	2,500,000.00		15.00	.006%	.008%	9	TTL	5.00	35.00	DIP
8519749	C	2,621,440.00		15.00	.005%			TTL	5.00	.00	DIP
4429664	C	3,000,000.00		10.00	.5%	.6%	9	TTL	5.00	35.00	DIP
8493814	C	3,579,545.00	COMP	5.00	.04%	.05%		TTL	5.00	35.00	DIP
2396960	E	4,000,000.00	1,000,000	5.00	.004%	.006%	5	TTL	5.00	35.00	TO-8
4430008	C	4,000,000.00		5.00	.05%	.06%	9	TTL	5.00	35.00	DIP
4430076	C	4,717,400.00		10.00	.01%	.01%	9	TTL	5.00	35.00	DIP
1589408	E	4,915,200.00		10.00	.004%	.006%	2	TTL	5.00	35.00	TO-8
2397044	E	4,915,200.00		10.00	.004%	.006%	2	TTL	5.00	35.00	TO-8
8493409	C	4,915,200.00		15.00	.008%	.01%		TTL	5.00	35.00	DIP
8519177	C	5,120,000.00		10.00	.01%	.01%		TTL	5.00	.00	DIP
4430037	C	6,000,000.00		5.00	.004%	.006%	9	TTL	5.00	35.00	DIP
8493414	C	6,144,000.00		5.00	.01%	.01%		TTL	5.00	35.00	DIP
1582532	E	7,000,000.00		10.00	.004%	.006%	2	TTL	5.00	35.00	TO-8
8519178	C	7,234,000.00		10.00	.01%	.01%		TTL	5.00	.00	DIP
1582500	E	7,372,800.00		10.00	.004%	.006%	2	TTL	5.00	35.00	TO-8
6833138	C	7,500,000.00		10.00	.1%	.1%	9	TTL	5.00	35.00	DIP
5616635	C	7,680,000.00		5.00	.004%	.006%	9	TTL	5.00	35.00	DIP
5615755	E	7,987,200.00		10.00	.004%	.006%	2	TTL	5.00	35.00	TO-8
2410165	E	8,000,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
5615753	E	8,000,000.00		10.00	.002%	.004%	6	ECL	4.25	.00	TO-8
8519576	C	8,000,000.00		5.00	.006%	.006%		TTL	5.00	.00	DIP
2397049	E	8,695,000.00	COMP	5.00	.004%	.006%	4	TTL	5.00	35.00	TO-8
1582988	E	9,000,000.00		5.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8519175	C	9,042,000.00		10.00	.01%	.01%		TTL	5.00	.00	DIP
1582564	E	9,090,000.00		5.00	.004%	.006%	4	TTL	5.00	35.00	TO-8
2397062	E	9,541,900.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
4430045	C	9,720,000.00		5.00	.004%	.006%	9	TTL	5.00	35.00	DIP
8519500	C	9,720,000.00	9720000	5.00	.004%	.006%	9	TTL	5.00	35.00	DIP
2396875	E	9,830,400.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
2397082	E	9,835,700.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
5616004	E	9,849,600.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
2397050	E	10,000,000.00	COMP	5.00	.004%	.006%	4	TTL	5.00	35.00	TO-8
4429947	C	10,000,000.00	COMP	5.00	.004%	.006%	9	TTL	5.00	35.00	DIP
5615371	E	10,752,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
1582531	E	11,200,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
4481464	A	11,664,000.00		5.00	.004%	.006%		TTL	5.00	35.00	DIP
2396788	E	11,796,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8

PG. 2 06/30/82 23:36 UR0206 *** IBM INTERNAL USE *** COMPONENT DATA BANK INTERNAL USE ONLY
CDB/OSC ALL/OSC TECH OSC/PAR1 SEQ/LH OSC/FREQ/HZ1 NO/LIMIT.

PART NUMBER	TUC	FIRST O/P FREQUENCY HERTZ	SECOND O/P FREQUENCY HERTZ	SYM- METRY %	FREQ. TOL. % 25 DEG C	FREQ. TOL. % 0TO70	FAM- ILY	TECH- NOLOGY	INPUT VOLTAGE +-10%	MAXIMUM CAP.LD. P.F.	CAN SIZE
4429707	C	12,000,000.00		10.00	.004%	.006%	10	TTL	5.00	35.00	DIP
1582989	E	12,500,000.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8519176	C	12,800,000.00		10.00	.01%	.01%		TTL	5.00	.00	DIP
1589283	E	13,824,000.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
2410083	E	14,000,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8493782	C	14,152,300.00		10.00	.008%	.01%		TTL	5.00	35.00	DIP
1589284	E	14,688,000.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8493554	C	14,745,600.00		10.00	.004%	.006%		TTL	5.00	35.00	DIP
2410055	E	15,091,200.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
2397020	E	15,552,000.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
4481935	E	15,552,000.00		5.00	.004%	.006%		TTL	5.00	35.00	TO-8
2410196	E	16,000,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8279298	C	16,000,000.00		15.00	.035%	.045%	10	TTL	5.00	35.00	DIP
8493355	C	16,588,800.00		10.00	.01%	.01%		TTL	5.00	35.00	DIP
8493500	C	17,000,000.00		15.00	.004%	.006%		TTL	5.00	35.00	TO-8
8519702	C	17,241,400.00		10.00	.35%	.40%		TTL	5.00	.00	DIP
4429685	E	18,000,000.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8519575	C	18,000,000.00		15.00	.035%	.045%		TTL	5.00	.00	DIP
5617084	E	18,181,800.00	0	10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8493413	C	18,200,000.00		15.00	.035%	.045%		TTL	5.00	35.00	DIP
4429943	C	18,432,000.00		15.00	.035%	.045%	10	TTL	5.00	35.00	DIP
5616003	E	19,660,800.00		10.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
4429906	C	19,968,000.00		5.00	.004%	.006%	10	TTL	5.00	35.00	DIP
1582620	E	20,000,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8493207	C	20,000,000.00		5.00	.008%	.010%	10	TTL	5.00	35.00	DIP
8493204	C	20,007,000.00		5.00	.0040%	.0060%	10	TTL	5.00	35.00	DIP
8493423	C	20,480,000.00		10.00	.01%	.01%		TTL	5.00	35.00	DIP
4429937	C	20,833,000.00		10.00	.35%	.4%	10	TTL	5.00	35.00	DIP
5615989	E	21,504,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
4430046	C	21,582,700.00		5.00	.004%	.006%	10	TTL	5.00	35.00	DIP
4481730	C	21,792,000.00		5.00	.008%	.01%		TTL	5.00	35.00	DIP
2397042	E	24,000,000.00		15.00	.004%	.006%	3	TTL	5.00	35.00	TO-8
8493356	C	24,000,000.00		5.00	.1%	.1%		TTL	5.00	35.00	DIP
8272248	C	25,000,000.00		10.00	.1%	.1%	10	TTL	5.00	35.00	DIP
4430021	E	26,666,600.00		10.00	.0025%	.0025%	8	TTL	5.00	35.00	TO-8
8493533	C	28,571,400.00		5.00	.004%	.006%		TTL	5.00	35.00	DIP
4481795	C	32,000,000.00		10.00	.004%	.006%		TTL	5.00	35.00	DIP
6833170	E	32,000,000.00		10.00	.004%	.006%	8	TTL	5.00	35.00	TO-8
6833178	E	35,714,300.00		10.00	.01%	.02%		ECL	4.25	.00	TO-8
5616807	E	36,363,600.00		10.00	.004%	.006%	8	TTL	5.00	35.00	TO-8
6833176	E	37,037,000.00		10.00	.01%	.02%	6	ECL	4.25	5.00	TO-8
6833174	E	38,461,500.00		15.00	.01%	.02%		ECL	4.25	35.00	TO-8
4429905	C	40,000,000.00		10.00	.004%	.006%	10	TTL	5.00	35.00	DIP
5615754	E	40,000,000.00		5.00	.01%	.02%		ECL	4.25	5.00	TO-8
8519559	C	40,000,000.00		.00	.004%			ECL	5.00	5.00	DIP
8493537	E	40,816,300.00		.00	.01%			ECL	4.25	.00	TO-8
8493846	C	48,000,000.00		5.00	.004%	.006%		TTL	5.00	35.00	DIP
4481264	C	50,000,000.00		10.00	.1%	.1%		TTL	5.00	35.00	DIP
4430083	C	58,982,400.00		10.00	.005%	.01%		ECL	5.00	35.00	DIP
8493553	C	70,000,000.00		15.00	.004%	.006%		TTL	5.00	35.00	DIP

TOTAL RECORDS 98