Table 8.1

s/n	CUTTING	NAME	VIBRATION MODE	FREQUENCY AREA (KHZ)	DRIVING LEVEL (MW) MAX	C_0/C_1	NOTES
1	Double X+5°	J	Longitudinal	0.8~10	0.2	190~250	It is used in oscillators. The almost zero coefficient is noticed in room temperatures. It works in furnaces equipped with temperature control systems.
2	XY	Commercial name	Longitudinal or breadthwise	3~50	0.1	600~900	It works in furnaces, especially in the optimum frequency area.
3	NT	N	Longitudinal	4~150	0.1	800~1500	It is used mostly in filters and oscillators of low frequencies. They work in a wide temperature area, with stability ±5ppm for variation of ±5°C, as long as the working temperature area is controlled. In room temperatures it can work with stability ±0.0025% without temperature control.
4	X+5°	H	Curve	5~140	0.1	225	The relatively big divergence in frequency in the working temperature area reduce the applications in filters because of the environmental control. Its characteristics are the small temperature coefficient and the big ratio of storing mechanical energy to electric energy. It is used in wide-band filters and in oscillators with Trs, where the LC networks are not stable and there are space problems. The disadvantages are the constructing difficulties.
5	BT	B	Thickness	1~75	-	-	Suitable for high frequencies. Its disadvantage is the large thickness for low frequencies and the construction difficulties. The zero temperature coefficient occurs in a very small area of temperatures. It's not effective as AT.
6	X-18.5°	F	Expansive	50~250	-	200	It is used mostly in filters where the low temperature coefficient is sacrificed for having better response of frequency. Suitable for many electrodes.
7	X+5° or EN	E	Expansive	50~250 or (10~100)MHz in the 3rd and 5th harmonic	2	130~160	It is used mostly in filters of low frequencies because its ratio Co/C_1 and its temperature coefficient are small.
8	DT	D	Shear	8-~500	2	450	Suitable for applications with and without furnace. The relatively small ratio

							C_0/C_1 allows applications in filters. It is used as regulation crystal and time base in frequency counters. Also, in FM and TV transmitters. The disadvantage is the not so good operation above 500KGz.
9	MT	M	Expansive	5~250	2	250	Its small temperature coefficient allows it to be used in control oscillators and filters but the small ratio C_0/C_1 requires low complex resistance. It is rarely used as it has been replaced by other crystals.
10	GT	G	Expansive	85~400	0.1	375	It is more stable than everyone else; it doesn't change more than 1ppm for an area of 100°C. Its temperature coefficient is small for a big area of frequencies, in combination with another vibration mode which has almost the same range and frequency equal to 8.86 times the natural frequency. It is used in frequencies where the stability without temperature control or the low complex resistance are necessary. Its disadvantage is the high cost compared with the other types, which is due to the manufacturing difficulties it shows.
11	CT	C	Shear	100~600 and 300~1100	2	350~400	It has almost zero temperature coefficient in lo frequencies. It is used in oscillators and in low frequency filters and doesn't require temperature control for working in the harmonics. In filters, it is used because its ratio C_0/C_1 and in oscillators because it has a small series resistance, especially above 400KHz. Its disadvantage is the bog dimensions and consequently the manufacturing difficulty of the crystal for very low frequencies.
12	X or Curie	Commercial name	Expansive	350~20000	-	-	Economical and mechanically stable cutting mode. Its disadvantage is the high temperature coefficient, which has a tendency to 'jump' form one vibration mode to another.
13	SL	Commercial name	Shear in conjunction with Curve	300~800	-	450	Electrical attributes similar to DT, but bigger and with higher Q and similar attributes above 200KHz. They are adjusted for some filter applications

							when manufactured.
14	Y	Y	Thickness or shear	500~20000	-	-	Very efficient. It shows high mechanical storing in relation with the electric energy. Its disadvantage is the high temperature coefficient, the difficult mechanization and the poor frequency range.
15	AT or Z<φ	A	Thickness	Basic 550~40000 3rd harmonic (10~80)Mz 5th harmonic (55~150)MHz 9th harmonic (150~250)MHz	1~8	10~100000	Great properties in temperature and frequency. In its harmonics, it is used when frequency must not change when the reaction of the oscillator changes. It is equipped with such attributes that it meets the need for 70~80% of the requirements in crystals. It is preferred in high frequencies oscillators with control, where the varied temperature range is handled. This is due to the fact that its small size conforms to the strict specifications. Its disadvantage is the manufacturing difficulties for optimal operation, without coupling between the various vibration modes.

There are also the SC, JT, P cuttings.

The industrial production of crystals, for AT cutting as well as for other cuttings, is done mostly by the following procedure:

1. Gross cutting of the crystal for a given cutting angle,
2. Cutting of a chop of crystal with a special angle,
3. Measurement of the angle, of the crystal chop, in degrees, minutes, seconds, with x-rays for the success of the required frequency,
4. Exterior process (continual rubbing) in order to avoid other vibration modes except for the required,
5. Placing of mask on the crystal chop (0.1μm) for achieving the required frequency (lapping),
6. Specification, on the chop, of the required vibration mode (beveling), only for using the crystal in low frequencies,
7. Chemical removal of the mask created on the chop in steps 5 and 6 (etching),
8. Manufacture of electrodes on the chop (from Al, Ag, Au etc.) with sublimation by a special device,
9. Propping of the crystal chop on a fixed basis, with conductive acetic glue or conductive cement,
10. Placing of more electrode material, on the basic electrode, for micrometric adjustment of the frequency of the crystal in the area of resonance frequencies,
11. Mechanical stamping of the crystal with its basis, in very low temperature and N and R environment for avoiding future oxidation,
12. Final testing,
13. Imprinting of the elements on the component jacket.

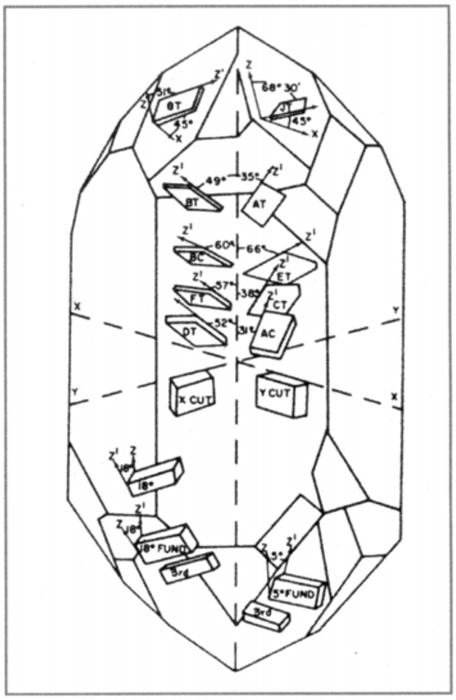

Figure 8.3

The crystals are working in the basic frequency as well as in the its harmonics, which are not whole multiples, however, they are very close to them.
Temperature affects the density, the dimensions and the elasticity Y^E of the crystal. Because the elastic constants of the crystal are either positive or negative (see chapter 7), the temperature coefficient of temperature alteration can be positive, zero or negative, depending on the cutting mode, the oscillation mode and the shape of the terminal surfaces. In Fig. 8.4a we show you the frequency change in relation with temperature, for various cutting modes, while in Fig. 8.4b, we show you the volume $\Delta f/f$ in relation with temperature fir AT cutting and various cutting angles. When a fixed operation frequency is required, the crystal is placed in a temperature-monitored oven. In addition, the crystal is included in an air-void capsule or with inactive gas, so as to avoid oxidation and losses caused by the creation of supersounds within the air. Some cuttings can be predicted with air void, whose adjustment allows for small change in frequency. In Fig. 8.5a and b, we show you two different connections of quartz crystal.

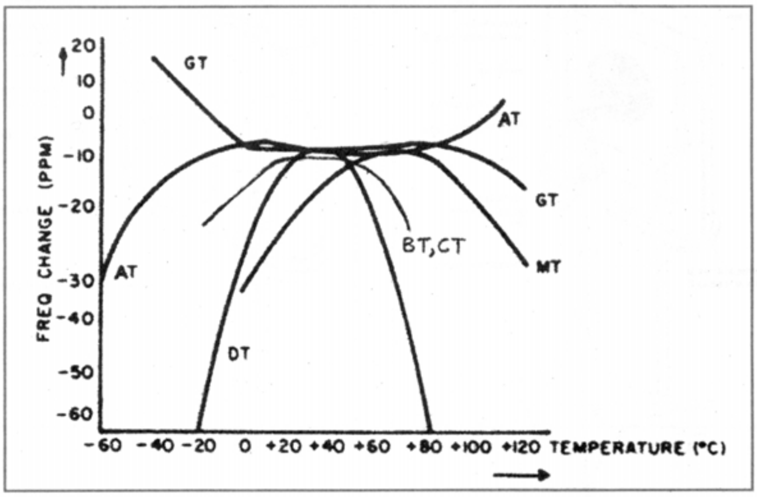

Figure 8.4a

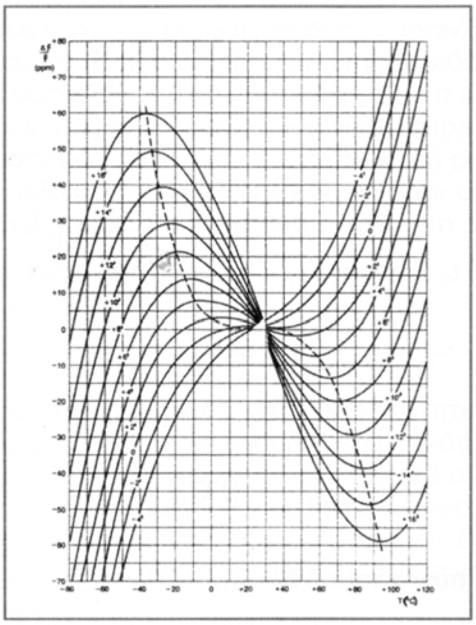

Figure 8.4b

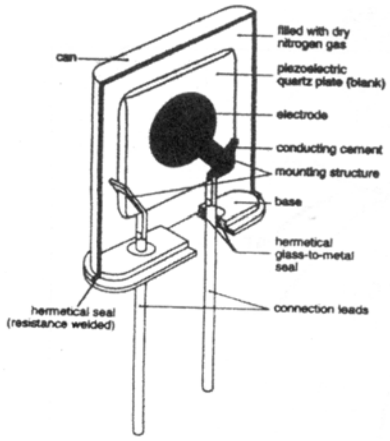

Figure 8.5a

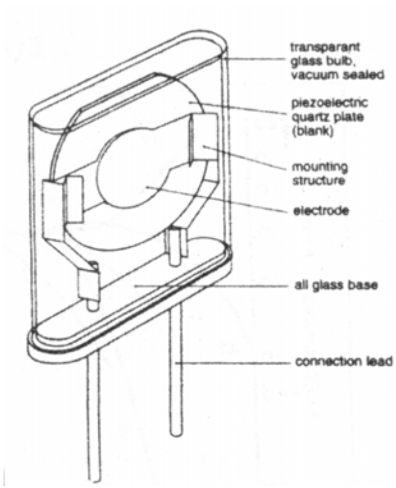

Figure 8.5b