SECTION 2

QUARTZ CRYSTAL UNITS

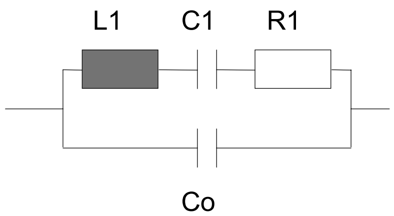
TECHNICAL INFORMATION

1. INTRODUCTION

Quartz, chemically known as SiO_2 is a piezoelectric material. It is therefore possible, by using certain cuts to obtain a resonance at a stable and defined frequency. The high quality factor and the low dependence on external influences make crystal units highly suitable for stabilising the frequency of an oscillator.

2. ELECTRICAL PARAMETERS

The simplified electrical equivalent circuit of a quartz crystal can be shown as:



where L1 is the motional inductance, C1 the motional capacitance and R1 the motional resistance of the crystal. The Co represents the shunt (or parallel) capacitance of the crystal and its electrodes.

The QUALITY FACTOR (Q) can be calculated as follows:

$$Q = \frac{L1 \; 2\Pi \; Fs}{R1} = \frac{1}{R1 \; C1 \; 2\Pi \; Fs}$$

where Fs is the series resonant frequency.

The 2 main resonance's (Fp and Fs) are related by :

$$Fp = Fs \left(1 + \frac{C1}{2\,Co}\right)$$

where Fp is the parallel resonant frequency

The resonance with a series load capacitance (CL) is shown by :

$$Fl = Fs \left(1 + \frac{C1}{2\,(Co + CL)}\right)$$

The frequency of a crystal resonator can be trimmed by changing the load capacitance value of the oscillator circuit and the following relationship then applies :

$$DL = \frac{C1}{2(Co + CL)}$$

where DL is the relative change between Fl and Fs.

The equivalent series resistance (ESR) is the equivalent resistance of the crystal near its series resonance (Fs).

3. TEMPERATURE CHARACTERISTICS

The relative variation of the frequency over the temperature range can be expressed by :

$$\frac{F - Fo}{F} = a1(T-To) + a2(T-To)^2 + a3(T-To)^3$$

where a1, a2 and a3 are respectively the 1st, 2nd and 3rd order temperature coefficients, and To is the ambient temperature (25°C). The temperature curve of low frequency crystals (below 1 MHz) is a parabola. High frequency crystals using the well known AT-cut always exhibit cubic curves within the usual temperature ranges.

TECHNICAL INFORMATION

4. CRYSTAL DRIVE LEVEL

The mechanical oscillation amplitude of a crystal plate is defined by :

$$W = Re\ I^2$$

where Re is the "effective" resistance of the crystal at load resonant frequency.

A too high power creates non-linear characteristics in the crystal equations and a frequency dependence on the drive level appears. For AT-cut crystals, a drive level of 1 mW is recommended, but lower values may be necessary in applications where low ageing and excellent temperature stabilities are requested.

For gate oscillators, a solution to reduce the drive level is to use small values of input and output capacitance's. However, too small values may often cut down input and output signals creating similar temperature stability problems as a high drive level. Therefore, a trade-off has to be found. An output resistor on the gate reduces these problems by limiting the crystal current but also reduces the total quality factor.

5. SPURIOUS MODES

Despite the fact that a crystal is designed to oscillate on only one mode, it can still vibrate at lower amplitudes on other unwanted modes, called spurious. These modes can be reduced below a certain level in dB compared to the main mode by optimising the crystal design.

7. AGEING

The frequency of quartz crystal will change with time. This ageing depends on several factors :

-manufacturing process
-type and material of the electrodes
-package style and sealing process
-atmosphere inside the package
-drive level
-factory pre-ageing
-operating temperature

8. ACTIVE MEASUREMENT METHODS

The frequency and the motional parameters can be measured with a TEST-SET, which has been standardised in the crystal industry. However, this method is limited in accuracy and cannot be used for high frequency crystals. Also, load capacitance's lower than 18 pF cannot be measured. A higher frequency accuracy can be obtained by measuring the crystals directly onto the customer oscillator. This avoids correlation problems.

9. PASSIVE MEASUREMENT METHODS

This method is described in the IEC-444 standard. The crystal is mounted onto a Π network in zero phase. It is the most accurate test procedure available today and it represents the only solution for high frequency crystals above 60 MHz. Crystals can also be tested using a network analyser, but correlation's are not yet fully agreed on an international base.

10. AVAILABLE TEST DATA

The following test data is available from FORDAHL:

-frequency at reference temperature
-motional parameters
-temperature curves
-ESR temperature curves
-temperature fit curves
-spurious response data
-ageing tests
-environmental data

A Certificate of Conformity to various international standards is also available.

11. CRYSTALS FOR OSCILLATOR APPLICATIONS

The use of quartz crystals into high stability applications or where special features are requested makes it necessary to take special care of several parameters when designing the oscillator and establishing the crystal specification.

Particular attention should be paid to the specification of the crystal parameters in relation to the oscillator performance. For some applications, C1, Co, ESR or the spurious attenuation have to be specified. Additional parameters such as frequency discontinuity and the ESR variation over temperature might also be very important for tight tolerance applications. For overtone or SC-cut crystals, a tuning circuit is necessary to guarantee oscillation on the desired mode.

The temperature stability, dependence on Vcc and load variations, the start up and the long term stability may depend heavily on taking these parameters into account when designing the circuit.

TECHNICAL INFORMATION

12. THE MOST COMMON CUTS AND VIBRATION MODES

Piezoelectric quartz crystal units are made from small pieces of crystal, or blanks, cut from a block of quartz. The orientation of the cut compared to the atomic axis of the crystal defines the way, or mode, of vibration of the crystal blank as well as its frequency stability versus temperature characteristics.

The standard sizes of packages restrict the crystal blanks mechanical dimensions. The table below shows the atomic axis, vibration mode and resulting frequency range of the various cuts commonly used.

DOMAIN	CUT	VIBRATION MODE	FREQUENCY RANGE
LOW FREQUENCY RANGE	XY	flexure	4 to 20 kHz
	NT	flexure	15 to 100 kHz
	X+5°	extensional	50 to 200 kHz
	CT	face shear	150 to 850 kHz
	SL	face shear	175 to 850 kHz
	DT	face shear	200 to 1000 kHz
HIGH FREQUENCY RANGE	AT	thickness shear, fundamental	1 to 50 MHz
	AT	thickness shear, 3rd overtone	4 to 150 MHz
	AT	thickness shear, 5th overtone	4 to 200 MHz
	AT	thickness shear, 7th overtone	100 to 250 MHz
	SC	thickness shear, fundamental	2to 35 MHz
	SC	thickness shear, 3rd overtone	5 to 100 MHz
	SC	thickness shear, 5th overtone	5 to 150 MHz

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FREQUENCY CONTROL PRODUCTS

CRYSTAL ORDERING CODES

SOME EXAMPLES...								
	1		2	3	4	5	6	7
HC-49/U	DF49	32.768 MHz	20	B	3		C	10
HC-45/U	DF45	10.752 MHz	00			X	H	100
HC-50/U	DF50	5.000 MHz	30	A			D	5

1. PACKAGE CODE

CODE	MIL. NO.	IEC NO.	OTHER	SEALING	CODE	MIL. NO.	IEC NO.	OTHER	SEALING
DF45	HC-45/U	EB		RW	DF49D			SMD 49/4	RW
DF01			UM-1	RW	DF01D			SMD UM-1	RW
DF05			UM-5	RW	DF05D			SMD UM-1	RW
DF49	HC-49/U	RC		RW	DF06D			SMD	RW
DF50	HC-50/U	RX		RW	DF07D			SMD	RW
RW = RESISTANCE WELD									

2. LOAD CAPACITANCE	3. FREQUENCY ADJUSTEMENT	4. MODE	5.INDICATION CODE	6.TEMPERATURE RANGE	
The code shows the load capacitance value in pF (20 = 20 pF). For series resonance, the code "00" applies.	VOID = ± 10 ppm A = ± 5 ppm B = ± 20 ppm D = ± 30 ppm C = ± 50 ppm E = ± 100 ppm	VOID = fundamental 3 = 3rd overtone 5 = 5th overtone 7 = 7th overtone 9 = 9th overtone	VOID = temperature stbility only X = overall tolerance	A = 0 to 50°C L = 0 to 60°C B = 0 to 70°C M = -10 to 50°C D = -10 to 60°C I = -10 to 70°C Q = -20 to 60°C C = -20 to 70°C P = -25 to 75°C K = -30 to 60°C R = -30 to 70°C N = -30 t o 75°C	F = -40 to 70°C E = -40 to 85°C G = -55 to 105°C H = -55 to 125°C OA= 55°C ± 5°C OE= 60°C ± 5°C OB= 65°C ± 5°C OF= 70°C ± 5°C OC= 75°C ± 5°C OG= 80°C ± 5°C OD= 85°C ± 5°C

7. FREQUENCY STABILITY

frequency stability expressed in ppm, either as an overall tolerance or as temperature stability only.

8. NON-STANDARD SPECIFICATIONS

Specifications that cannot be covered by the above codes will be issued a unique specification number

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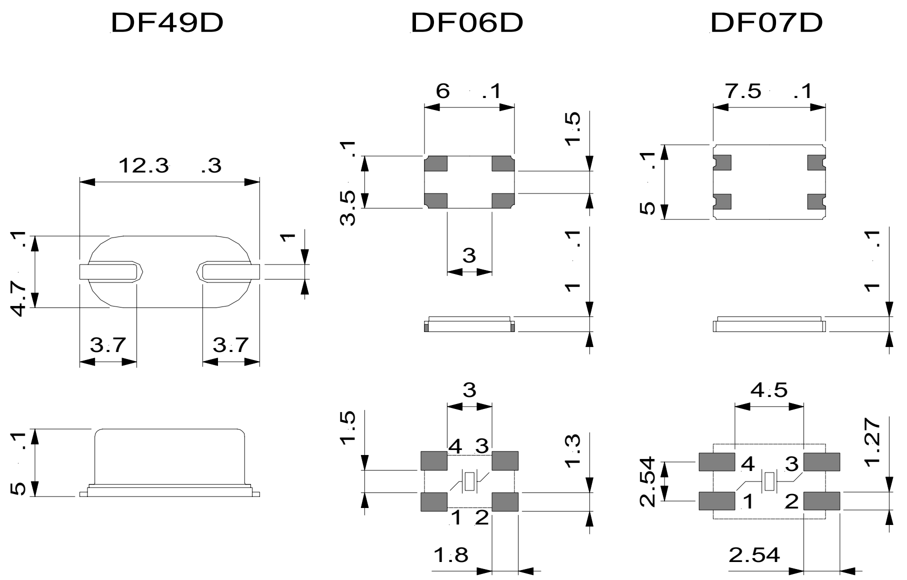
SURFACE MOUNT CRYSTALS
DF49D, DF06D & DF07D

METAL AND CERAMIC SMD PACKAGES



TYPE	**DF49D, DF06D, DF07D**
Frequency Range	3.2 to 150 MHz

ELECTRICAL CHARACTERISTICS				**detailed specification [ppm]**					
type	model code	frequency range (MHz)	mode	ESR max.	stability -10 to 60°C	calibration @ 25°C	drive level(typ.)	Co max	load capacitance
DF49D	CD50	3.2 to 25	fund	200 to 50 Ω	≤ ± 50	≤ ± 50	0.1 mW	≤ 7 pF	18 to 32 pF or series resonance.
	C3D50	25 to 60	3rd	100 Ω					
DF06D	M10	12 to 50	fund	50 Ω	≤ ± 5	≤ ± 10			
	3M10	50 to 60	3rd	90 Ω					
DF07D	M10	10 to 40	fund	50 Ω	≤ ± 5	≤ ± 10			
	3M10	40 to 100	3rd	70 Ω					
remarks	1st year ageing at 25°C is ≤ ± 5 ppm								
	Above values are given as indications only.								
	Please contact us for your custom requirements.								
	Not all combinations of frequencies and specifications are available.								

ORDERING CODE	**type + frequency + CL value + temp. code**
Example	DF49D 32.768 MHz 00D5D50
	please refer to our crystal ordering code data-sheet (page 75) for more details

MINIATURE AT-CUT CRYSTALS

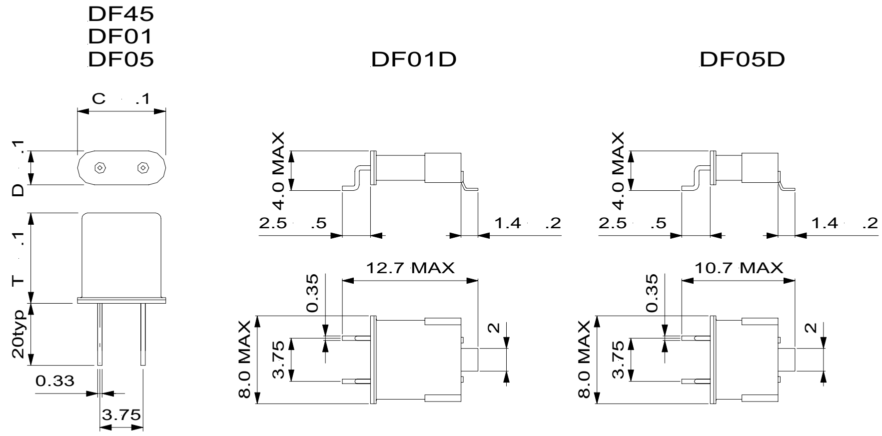
DF45, DF01 & DF05

HC-45/U, UM-1 & UM-5 PACKAGES

RESISTANCE WELD SEALING

WIDE FREQUENCY RANGE

ULTRA MINIATURE SIZE



Type	C	D	T
DF45	8.1	4.0	8.6
DF01	7.7	3.0	7.7
DF05	7.7	3.0	6.0

TYPE	DF45, DF01, DF05
Frequency Range	6 to 250 MHz

ELECTRICAL CHARACTERISTICS		detailed specification				
frequency range	mode	ESR max	C1 typ.	Co max.	drive level (typ.)	load capacitance
6 to 50 MHz (all types)	fund	200 to 20 Ω	8 to 25 fF	≤ 7 pF	0.1 mW	10 to 32 pF or series resonance.
16 to 50 MHz (DF05)			8 to 20 fF			
20 to 120 MHz (all types)	3rd	100 to 50 Ω	2 fF			
30 to 120 MHz (DF05)						
60 to 200 MHz	5th	150 to 100 Ω	0.5 fF			
85 to 250 MHz	7th	200 to 120 Ω	0.2 fF			

TEMPERATURE STABILITY	stability [≤ ppm]											
temperature range	stab.	code	stab.	code	stab.	code	stab.	code	stab.	code	stab.	code
-10 to 60°C	± 5	D5	± 7	D7	± 10	D10	± 20	D20	± 30	D30	± 50	D50
-20 to 70°C	± 7	C7	± 10	C10	± 20	C20	± 30	C30	± 50	C50	± 100	C100
-40 to 85°C	± 15	E15	± 20	E20	± 30	E30	± 50	E50	± 75	E75	± 100	E100
-55 to 105°C	± 25	G25	± 30	G30	± 50	G50	± 75	G75	± 100	G100	± 150	G150
remarks	adjustment tolerance ± 5 or ± 10 or ± 20 or ± 30 or ± 50 ppm (standard ± 10 ppm)											
	1st year ageing at 25°C is ± 2 to ± 5 ppm (standard ± 3 ppm)											
	Above values are given as indications only.											
	Please contact us for your custom requirements.											
	Not all combinations of frequencies and specifications are available.											

ORDERING CODE	type + frequency + CL value + adj. tol. code + mode code + temp. stab. code
Example	DF45 95.450 MHz 20A5G50
	please refer to our ordering code data-sheet (page 75) for more details

FREQUENCY CONTROL PRODUCTS

STANDARD AT-CUT CRYSTALS

DF49 & DF50

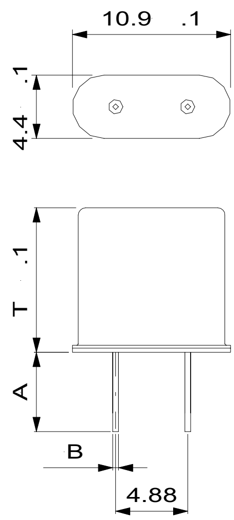
HC-49/U & HC-50/U PACKAGES

RESISTANCE WELD

WIDE FREQUENCY RANGE

MINIATURE SIZE

DF49
DF50



Type	A	B	T
DF49	20.00	0.46	13.46
DF50	6.05	1.02	13.46
DF49T	20.00	0.46	11.60
DF50T	6.05	1.02	11.60

TYPE	DF49, DF49T, DF50, DF50T
Frequency Range	2 to 250 MHz

ELECTRICAL CHARACTERISTICS		detailed specification				
frequency range	mode	ESR max	C1 typ.	Co max.	drive level (typ.)	load capacitance
2 to 50 MHz (DFxx)	fund	200 to 20 Ω	8 to 25 fF	≤ 7 pF	0.1 mW	10 to 32 pF or series resonance
4 to 50 MHz (DFxxT)			8 to 20 fF			
18 to 120 MHz	3rd	100 to 50 Ω	2 fF			
60 to 200 MHz	5th	120 to 80 Ω	0.5 fF			
85 to 250 MHz	7th	150 to 120 Ω	0.2 fF			

TEMPERATURE STABILITY	stability [≤ ppm]											
temperature range	stab.	code	stab.	code	stab.	code	stab.	code	stab.	code	stab.	code
-10 to 60°C	± 5	D5	± 7	D7	± 10	D10	± 20	D20	± 30	D30	± 50	D50
-20 to 70°C	± 7	C7	± 10	C10	± 20	C20	± 30	C30	± 50	C50	± 100	C100
-40 to 85°C	± 15	E15	± 20	E20	± 30	E30	± 50	E50	± 75	E75	± 100	E100
-55 to 105°C	± 25	G25	± 30	G30	± 50	G50	± 75	G75	± 100	G100	± 150	G150
remarks	adjustment tolerance ± 5 or ± 10 or ± 20 or ± 30 or ± 50 ppm (standard ± 10 ppm)											
	1st year ageing at 25°C is ± 2 to ± 5 ppm (standard ± 3 ppm)											
	Above values are given as indications only.											
	Please contact us for your custom requirements.											
	Not all combinations of frequencies and specifications are available.											

ORDERING CODE	type + frequency + CL value + adj. tol. code + mode code + temp. stab. code
Example	DF49 16.384 MHz 25E50
	please refer to our ordering code data-sheet (page 75) for more details
	please refer to our ordering code data-sheet (page 75) for more details

Technical Notes and Drawings

Technical Notes and Drawings