32kHz Design for Low Power Applications

Version 1.1

Reducing Power Consumption for 32kHz Quartz Crystal Oscillator Circuit

Abstract

The intent of this investigation is to show the advantages of 32kHz crystals with reduced C_L and lower ESR over conventional 32kHz crystals with regard to power consumption, oscillation allowance, starting time and drive level.

The following draft confirms the advantage of the use of Geyer Electronic KX-327NHT with Load Capacitance of 7pF instead of 12,5pF.

Part number 12.87153	**7pF**	**+/-20ppm**	**≤ 80k Ohm, 50k Ohm typ.**
Part number 12.87148	**7pF**	**+/-20ppm**	**≤ 50k Ohm, 35k Ohm typ.**

- Considerably reduced Power Consumption
- Improved Start up Performance
- Faster Start up time
- Stable operation for lower drive level

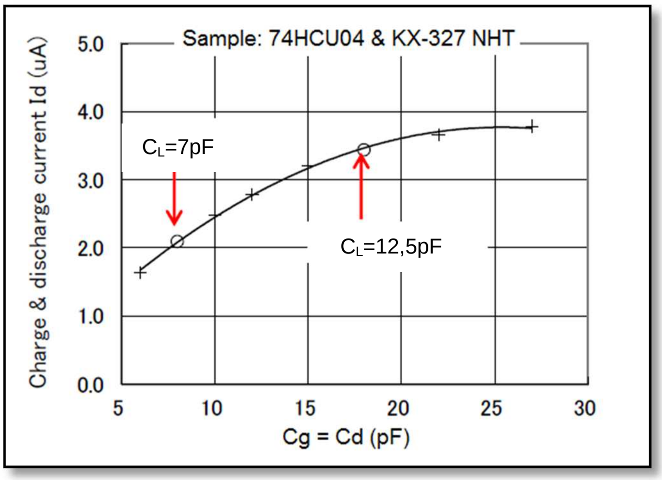
1. Reducing Power Consumption in CMOS Oscillator Circuit

Current consumption of the crystal oscillator circuit depend on power supply voltage (Vdd), frequency, load capacitance, and R1 of the quartz crystal.

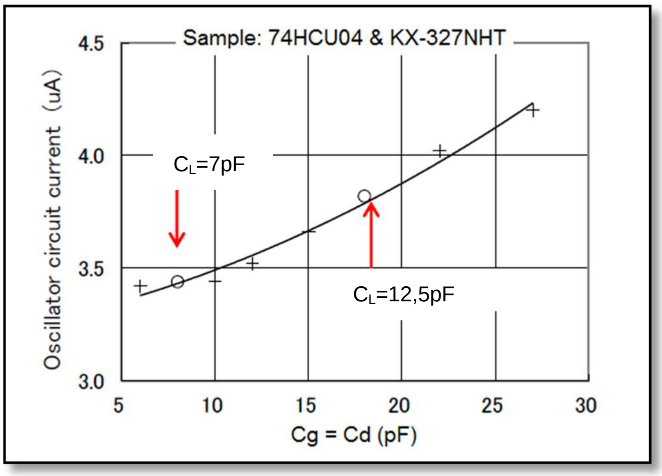
- Current consumption in the oscillator circuit
  1. Charge and discharge current of C_L » Low C_L
  2. Flow-through current » Low R1

- Low-C_L and Low-R1 of the quartz crystal realizes reduction of power consumption in the oscillator circuit

2. Relationship for C_L and Power Consumption in the Oscillator Circuit



Charge and Discharge Current
ID (Calculation)

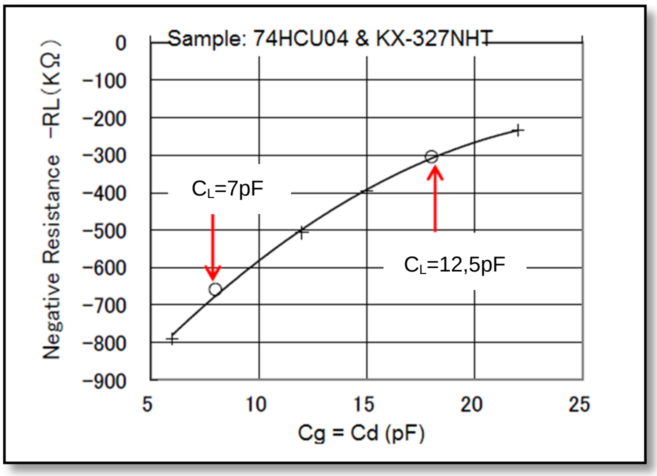


Oscillator circuit current
(Actual measurement)

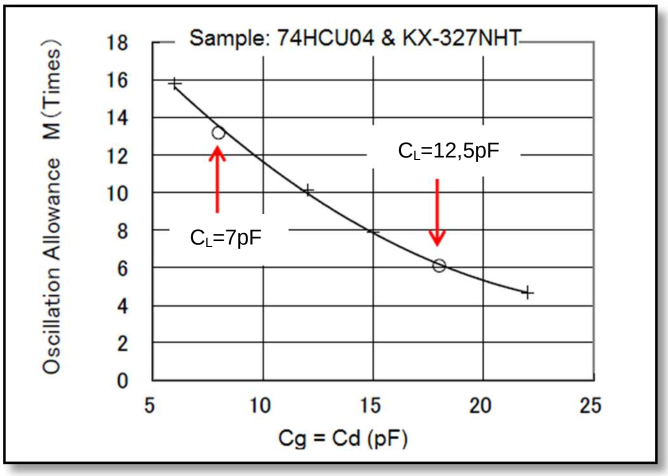
$$Id = \frac{Vd}{1/(2\pi f)C_d} = (2\pi f)VdC_d$$

- Charge and discharge current for C_L=7pF is 40% lower than for of 12,5pF.
- Actual measurement includes the flow-through current of the oscillation inverter. Therefore, when the flow-through current is controlled, the calculated values Approximate the actual reduction of the current consumption.

3. Relationship of Negative Resistance (Oscillation Allowance) and C_L



Negative Resistance $-R_L$ (KΩ)

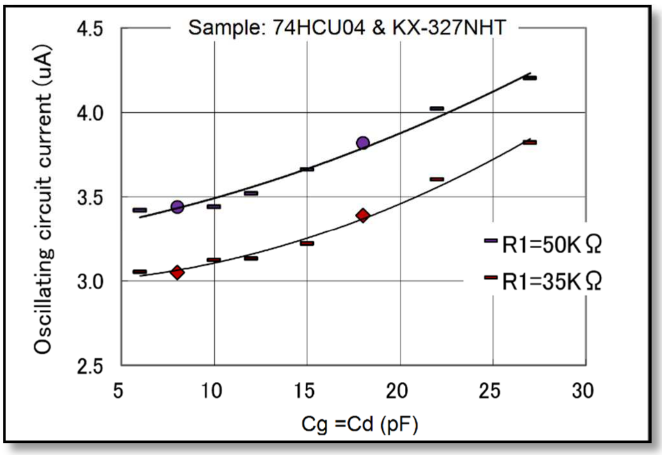


Oscillation Allowance M (Times)

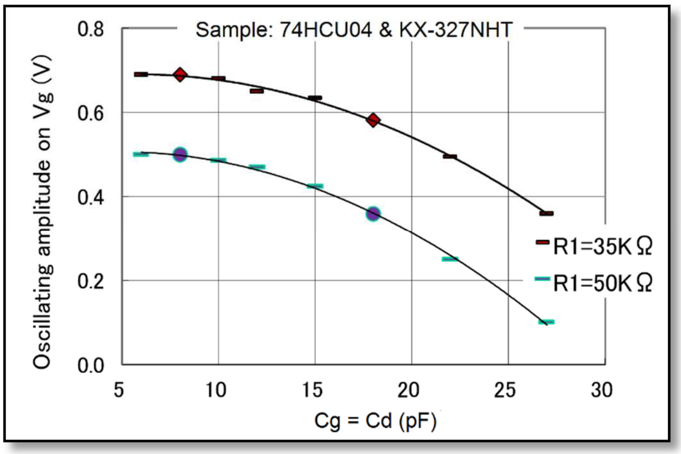
$$-R_L = \frac{-g_m}{(2\pi f)^2 C_g C_d}$$

Reduction of g_m and V_{dd} lowers the IC`s power consumption, which reduces the oscillation allowance. The Crystal`s low – C_L offsets the reduction of oscillation allowance.

4. Relationship for Oscillator circuit current and R1



Oscillator circuit current
(Actual measurement)

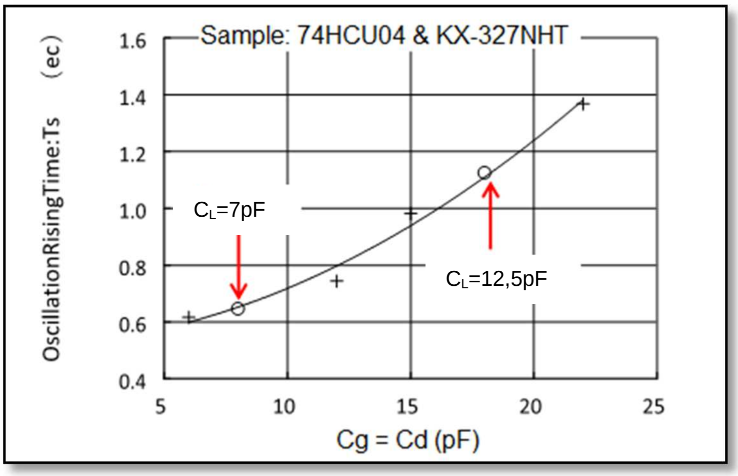


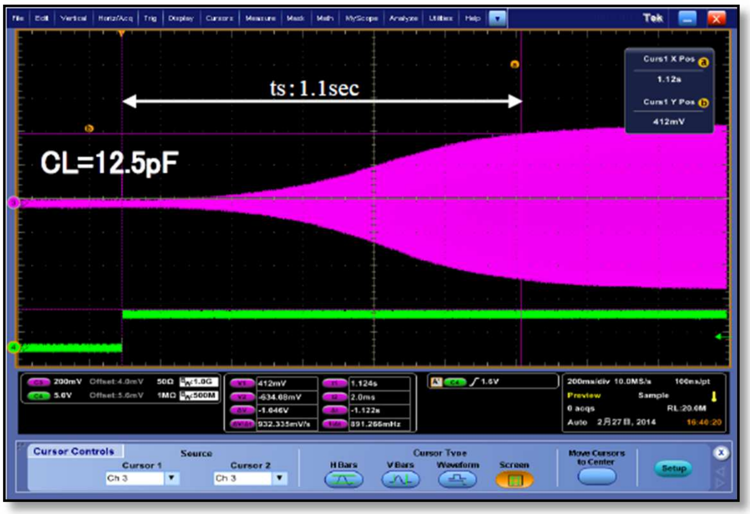
Oscillator amplitude on Cg (V)

- The current consumption of an oscillator circuit using 74HCU04 can decrease by Approximately 10% based on the quartz crystal motional resistance R1.
- Quartz crystal motional resistance R1 will be higher, the oscillator amplitude on Cg will be lower, and the flow-through current of oscillator will be higher.

5. Another Advantage of Low-C_L (Oscillation Rising Time)

Low C_L makes a higher negative resistance.
The oscillator rising time will be shorter
if the C_L is lower.

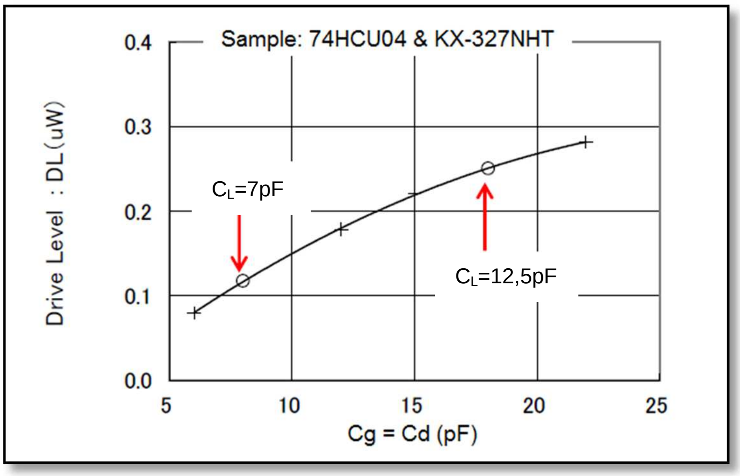




6. Another Advantage of Low-C_L (Drive Level)

DL = I² x Re

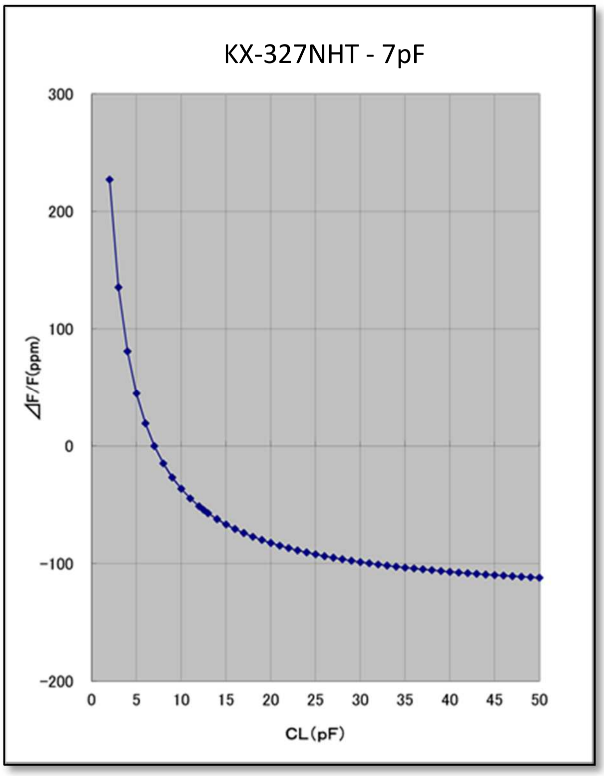
$I = Vg/ (1/\omega C)$
$Re = R1 \times (1+Co/C_L)^2$

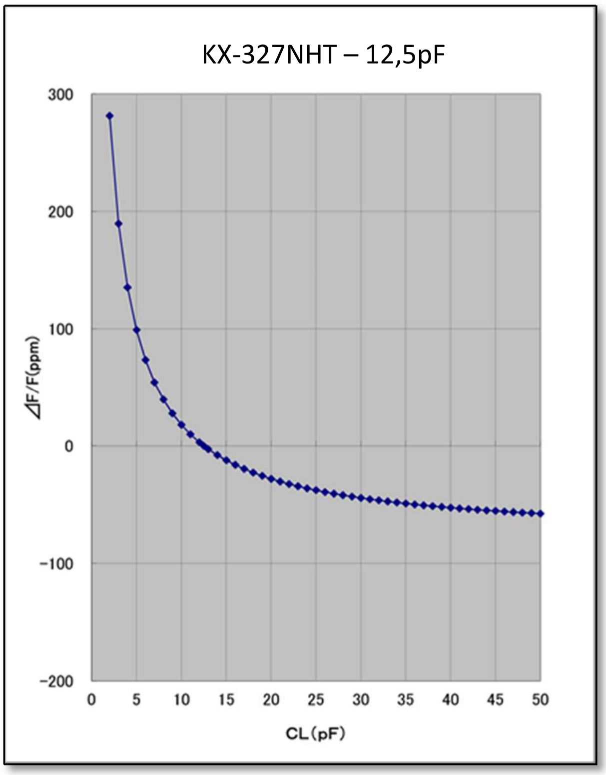


Lower C_L reduces the quartz crystal excitation current and reduced the drive level. Excessive drive level makes the characteristics of the tuning fork quartz crystal unstable.

7. Precision vs. Power Consumption

While a crystal with a low load capacitance of C_L = 7pF provides a design with low power consumption, a crystal with a higher load capacitance of C_L = 12,5pF is more advantageous for applications requiring higher precision.
As you can see from the diagram, the slope at C_L = 7pF is steeper than that at C_L = 12,5pF. This means that circuit tolerances have stronger influence on a 7pF-crystal than on a 12,5pF-crystal.





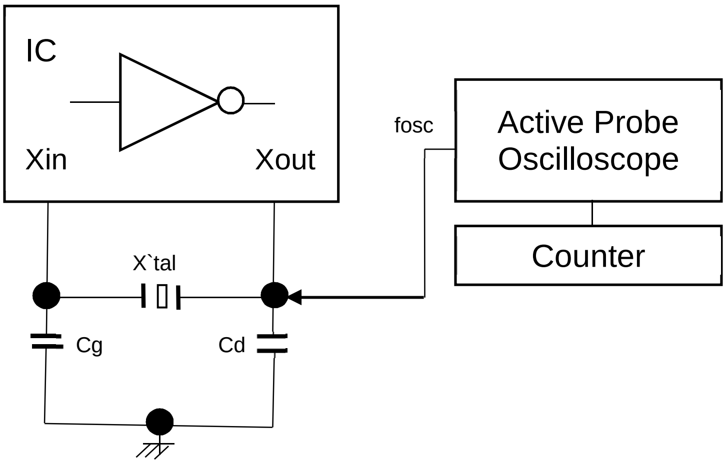
Therefore it is necessary to balance power consumption with precision.

Annex: Circuit Matching Investigation

Result of Matching Investigation

This is an example of our matching investigation for customers.

Our Crystal: KX-327NHT



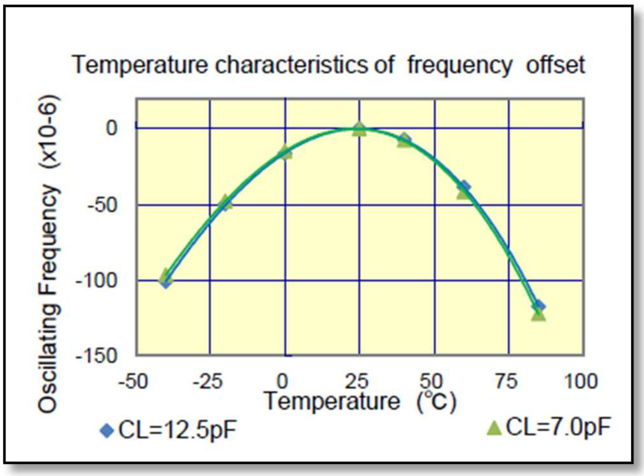


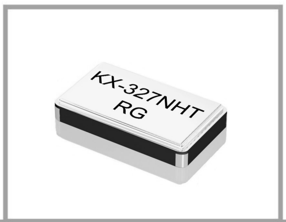
Table 1. Constants

Key specifications	A	B	Unit	Remarks
	C_L 12,5pF	C_L 7pF		
Vdd : V	3,3	3,3		
Capacitance at Input : Cg	20	6	pF	Optimal capacitance in response to C_L
Capacitance at Output : Cd	20	6	pF	

Table 2. Characteristic data

Item	C_L 12,5pF	C_L 7pF	Unit	Remarks
Matching accurancy : ⊿f/Fo	2,50	1,19	$x10^{-6}$	Frequency offset at specified Vdd
Voltage Fluctuation : +/-df/V	-	0,00	$x10^{-6}$	Vdd +/-10% (Standard operating voltage range)
Drive Level : DL	0,01	0,01	µW	DL=Ix2 Re < 1x10-6W, Re=R1 (1+Co/ C_L)2
Negative Resistance : I –RL I	-665	-1063	kOhm	5 times larger than R1MAX Judgemental standard of oscillation stability
Oscillation Allowance : M	9,5	15,2	Times	
Oscillation Starting Voltage	-	1,43	V	
Oscillation Stopping Voltage	-	1,36	V	

11/2015



Pb RoHS 2011/65/EU   REACH compliant   Conflict minerals free

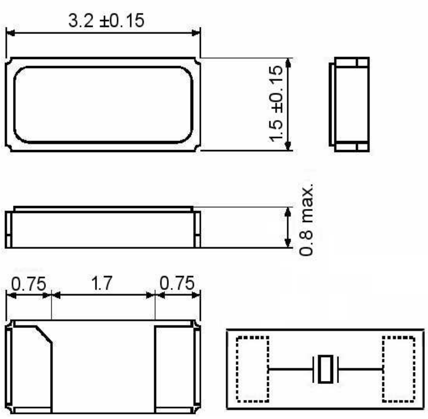
GEYER quartz technology

Quartz Crystal

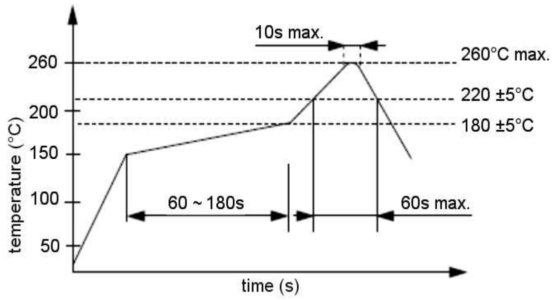
SMD-version

model	KX–327NHT
frequency	32,768 kHz
operating temperature	-40° ~ +85°C
frequency tolerance at +25°C	± 20 ppm
temperature tolerance (parabolic coefficient) at -40° ~ +85°C	-0,035 ppm/°C² typ.
turnover temperature	+25°C ± 5°C
storage temperature range	-55°C ~ +125°C
load capacitance C_L	7pF
motional capacitance (C1)	0,0036 pF, typ.
series resonance R_1 max.	80k Ohm
aging at +25°C (first year) max.	± 3 ppm max.
shunt capacitance C_o	1,3 pF (1,0 pF typ.)
drive level in µW max.	0,1 typ. (1,0 µW max.)
quality factor (Q)	20000 min.
reflow soldering condition	10 seconds at +260°C max. (2 times max.)
contents of reel	3000 pcs.
part no.	12.87153

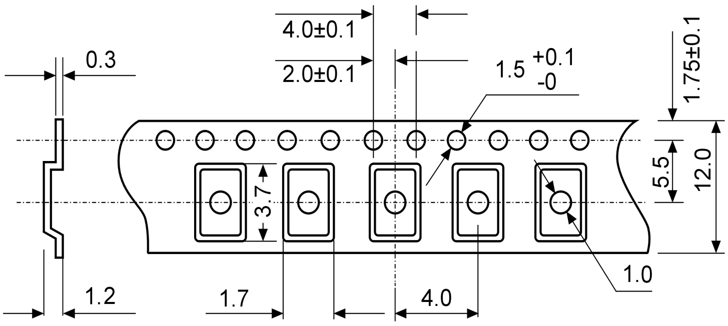
Dimensions (mm):



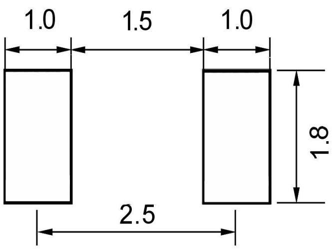
Reflow soldering condition:



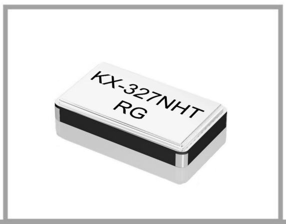
Tape specification:



Suggested soldering pad:



GEYER ELECTRONIC e.K. Lochhamer Schlag 5 82166 Gräfelfing/München
Tel. +49 89 546868-0 quartz@geyer-electronic.de www.geyer-electronic.de



RoHS 2011/65/EU REACH compliant Conflict minerals free

GEYER quartz technology

Quartz Crystal

SMD-version

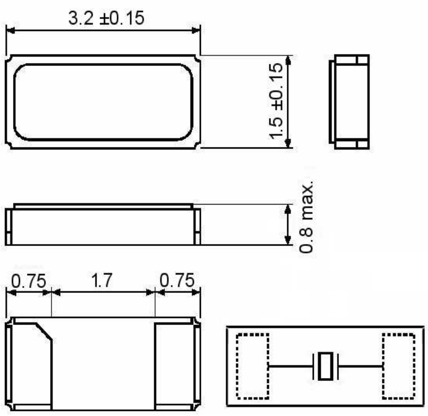
model	KX–327NHT
frequency	32,768 kHz
operating temperature	-40° ~ +85°C
frequency tolerance at +25°C	± 20 ppm
temperature tolerance (parabolic coefficient) at -40° ~ +85°C	-0,035 ppm/°C^2 typ.
turnover temperature	+25°C ± 5°C
storage temperature range	-55°C ~ +125°C
load capacitance C_L	7 pF
motional capacitance (C1)	0,0036 pF, typ.
series resonance R_1 max.	50k Ohm
aging at +25°C (first year) max.	± 3 ppm
shunt capacitance C_O	1,3 pF (1,0 pF typ.)
drive level in µW max.	0,1 typ. (1,0 µW max.)
quality factor (Q)	20000 min.
reflow soldering condition	10 seconds at +260°C max. (2 times max.)
contents of reel	3000 pcs.
part no.	12.87148

Remarks:

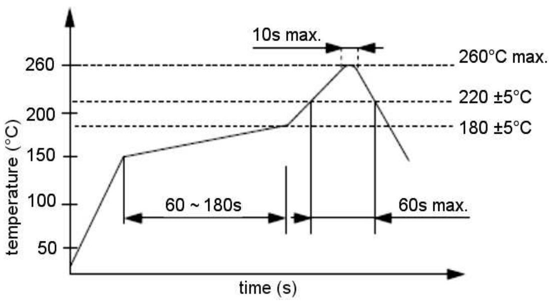
- Recommended for ST Microelectronics STM 32
  STM 8

  Recommended for Intel 8-series, PCH-LP, C220 series

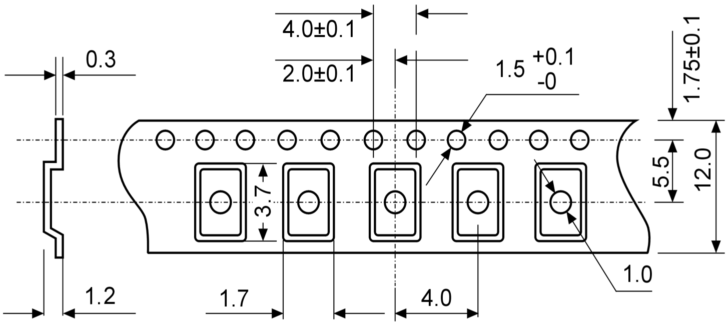
Dimensions (mm):



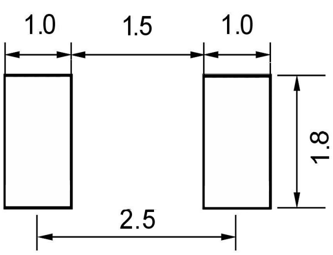
Reflow soldering condition:



Tape specification:



Suggested soldering pad:



GEYER ELECTRONIC e.K. Lochhamer Schlag 5 82166 Gräfelfing/München
Tel. +49 89 546868-0 quartz@geyer-electronic.de www.geyer-electronic.de

Version 03.11.2014

RoHS 2011/65/EU REACH compliant Conflict minerals free

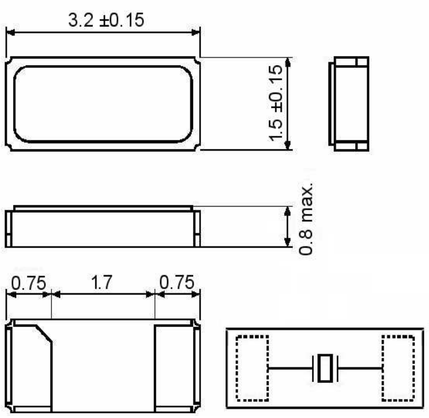
GEYER quartz technology

Quartz Crystal

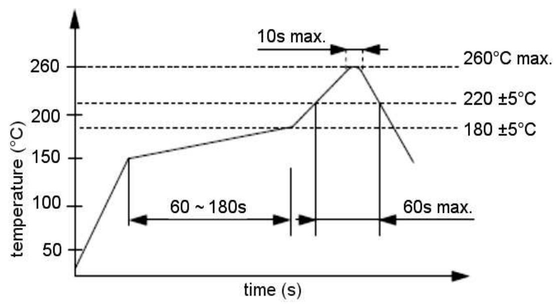
SMD-version

model	KX–327NHT
frequency	32,768 kHz
operating temperature	-40° ~ +85°C
frequency tolerance at +25°C	± 20 ppm
temperature tolerance (parabolic coefficient) at -40° ~ +85°C	-0,035 ppm/°C² typ.
turnover temperature	+25°C ± 5°C
storage temperature range	-55°C ~ +125°C
load capacitance C_L	12,5 pF
motional capacitance (C1)	0,0036 pF, typ.
series resonance R_1 max.	80k Ohm
aging at +25°C (first year) max.	± 3 ppm
shunt capacitance C_0	1,3 pF (1,0 pF typ.)
drive level in µW max.	0,1 typ. (1,0 µW max.)
quality factor (Q)	20000 min.
reflow soldering condition	10 seconds at +260°C max. (2 times max.)
contents of reel	3000 pcs.
part no.	12.87150

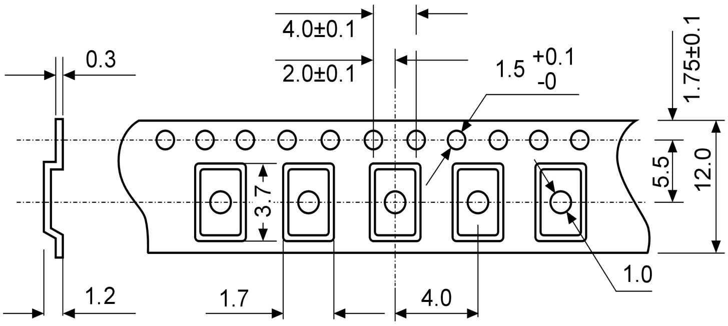
Dimensions (mm):



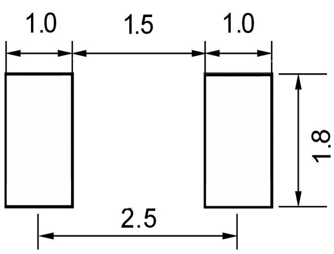
Reflow soldering condition:



Tape specification:



Suggested soldering pad:



GEYER ELECTRONIC e.K. Lochhamer Schlag 5 82166 Gräfelfing/München
Tel. +49 89 546868-0 quartz@geyer-electronic.de www.geyer-electronic.de

Version 03.11.2014