

Using LC oscillator circuits with Philips microcontrollers

AN456

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There are two basic types of LC oscillators, Colpits and Hartley. The Colpits is the two capacitor type shown in Figure 1. It is generally favored over the Hartley (shown in Figure 2). This is because of the simplicity of requiring only one inductor, which are generally more expensive and difficult to obtain than capacitors C2 and C1. Feedback is determined by the ratio of C2 and C1 (for our application, this is approximately 2:1). The center frequency for Figure 1 is given by:

$$f = \frac{\sqrt{(1/L_1) (1/C_1 + 1/C_2)}}{2\pi}$$

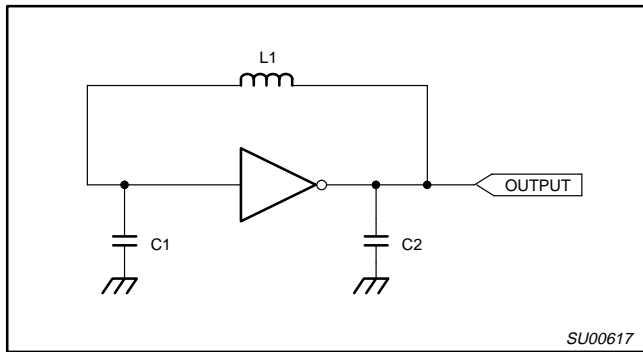


Figure 1. Colpits Oscillator

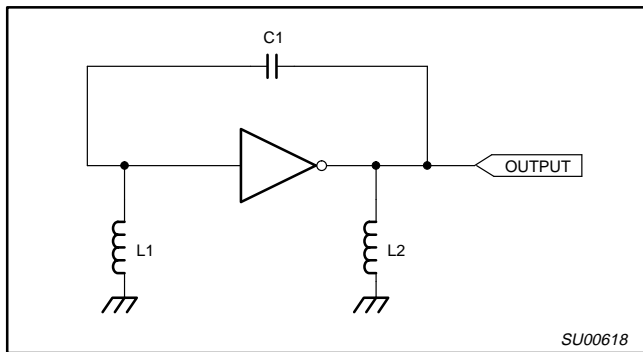


Figure 2. Hartley Oscillator

Table 1 contains measured frequencies for various combinations of inductor and capacitor values. The test circuit (Figure 1) was a Philips P87C750PBPN, using the internal inverting amplifier. The results compare well with the frequency predicted by the above formula at low frequencies. At higher frequencies, however, the gain of the amplifier becomes a significant factor, as do the internal capacitances of the device. The inductor identified as 10T0.16 is an air core coil 10 turns on a 0.16 diameter form using 26 gauge magnet wire close wound.

The inductors used in this test were TOKO types 5K, 5PH, 5P 5mm coils (adjustable ±5%). If the frequency is not critical, then a fixed inductor would be suitable. TOKO produces a range of inductors from 1µH to 1mH in the 144LY series. These are available from Digi-Key.

Table 1. Inductor and Capacitor Chart

INDUCTANCE (µH)	FREQUENCY (MHz)			
	C1 = 100p C2 = 220p	C1 = 47p C2 = 100p	C1 = 22p C2 = 47p	C1 = 10p C2 = 22p
680	0.8	1.1	1.5	2
470	0.95	1.3	1.8	2.4
220	1.3	1.9	2.6	3.3
100	1.9	2.7	3.7	4.8
68	2.4	3.3	4.6	6
47	2.8	4	5.6	7.4
22	4	5.7	7.8	10
10	5.9	8.3	11.4	15
6.8	7.2	10.2	14	18
4.7	8.7	12.3	16.7	21.5
2.2	12.8	18	25	31
1	19	27	37	50
0.68	24	33	46	
0.47	28	39	55	
10T0.16	35	47		

Table 2. Ceramic Capacitor Temperature Characteristics

EIA CODE	TEMPERATURE CHARACTERISTICS	COLOR CODE
M7J	P100 +120/-40PPM	Red/Violet
COG	NPO ±30PPM	Black
U1G	N075 ±30PPM	Red
P2G	N150 ±40PPM	Orange
R2H	N220 ±40PPM	Yellow
S2H	N330 ±60PPM	Green
T2J	N470 ±60PPM	Blue
U2J	N750 ±120PPM	Violet
P3K	N1500+ 500/-0PPM	Orange/Orange
Y5P	±10% ΔC from -30°C to +85°C	Yellow
Z5V	+22/-85% ΔC from +10°C to +85°C	Green

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TEMPERATURE COMPENSATION

Using a 6.8μH inductor, 47p and 100p capacitors gives a frequency of approximately 10MHz at room temperature. As the temperature changes, so do the values of both the capacitors and inductor. There is also an effect with the microcontrollers changing gain, however, this is small compared with the capacitors and inductor. This variation is shown in Figure 3. These results were obtained using NPO capacitors. NPO capacitors are zero temperature coefficient (nominally). Also available are other temperature coefficients (see Table 2). By trial and error we can pick one of these temperature coefficients which will compensate for the inductor. Just about all inductors have a positive temperature coefficient. Using an N750 for the capacitors C1 and C2, the following results were obtained (Figure 4). This a large improvement on the uncompensated design.

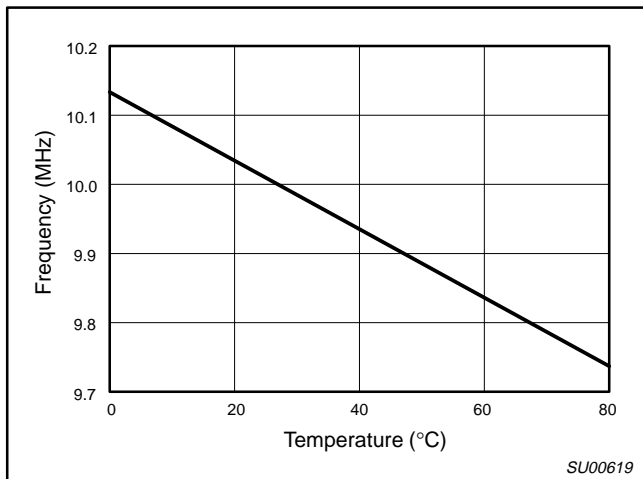


Figure 3. Frequency Variation Using NPO Capacitors

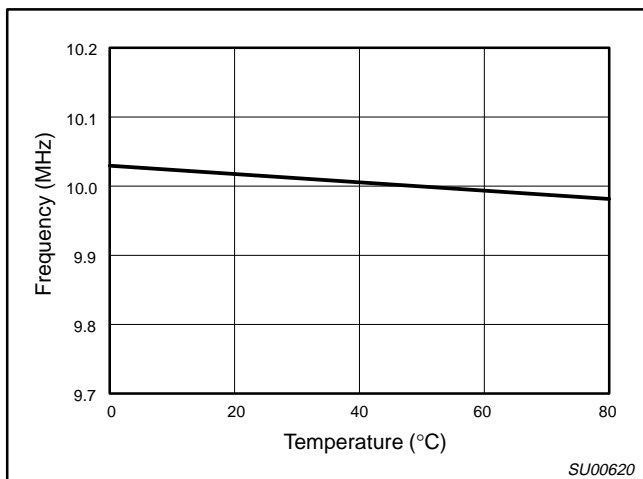


Figure 4. Frequency Variation Using N750 Capacitors

AIR WOUND INDUCTORS

The most expedient source of inductors are air wound (wind them yourself). Although probably not suitable for production, these offer the designer an infinite variation of inductance values. The table below gives a few useful values for use in microcontroller oscillators.

NUMBER OF TURNS (T)	INDUCTANCE (μH)	OSCILLATOR FREQUENCY (MHz) (with C1 = 47p; C2 = 100p)
10	0.3	47
15	0.68	32
20	1	27
25	1.5	23
30	1.8	21

All were close-wound with 26 gauge magnet wire on a 0.19" diameter form. Greater than 30 turns requires a permanent form.

START UP

Although an LC oscillator will start much quicker than a crystal oscillator after power is applied, this effect is not apparent in this application. Although the Q expressed as rate of change in impedance versus frequency of a crystal is very high, the losses can be quite large (resistive). This can lead to starting problems (given a low gain amplifier). With an LC oscillator the losses are much lower than with a crystal, thus the LC oscillator will start more reliably than a crystal oscillator.

SUPPLY VOLTAGE EFFECTS

Figure 5 depicts a Supply Voltage versus oscillator frequency graph for the test circuit shown in Figure 1, using C1 = 47p, C2 = 100p and L1 = 6.8μH.

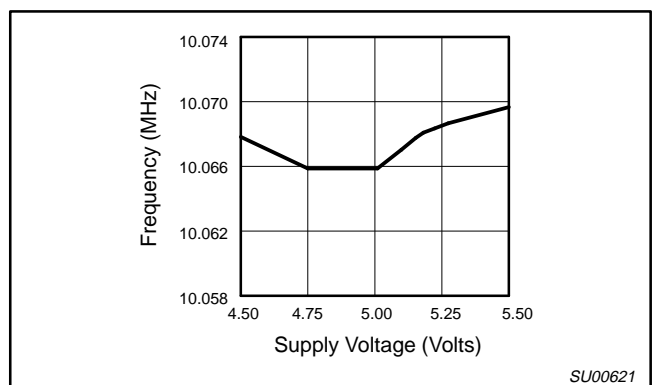


Figure 5. Supply Voltage vs. Frequency