Oscillator Characteristics of COPS™ Microcontrollers

National Semiconductor
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1.0 INTRODUCTION

COPS microcontrollers will operate with a wide variety of oscillator circuits. This paper focuses on two of the oscillator options available on COPS microcontrollers: the internal RC oscillator, and the crystal or inverter oscillator. The typical behavior of the RC oscillator with temperature and voltage (and typical values of R and C) is documented. For the crystal or inverter option, circuit configurations (RC, RL, RLC, R, LC, L) are presented which will allow the microcontroller to operate properly without the use of ceramic resonator or crystal.

The passive components used were inexpensive, uncompensated devices: standard carbon resistors, ceramic or foil capacitors, and air core or iron core inductors. To provide reasonably clear data on the characteristics of the microcontroller itself, no attempt at compensation for the external components was made.

2.0 RC OSCILLATOR OPTION

With the RC oscillator option selected, the graphs in *Figures 1* through *6* indicate the variation of the instruction cycle time of the microcontroller with temperature and voltage. Typical R and C values, as recommended in the respective device data sheets, were used. The graphs are composite graphs reflecting the worst case variations of the devices tested. Therefore, the graphs show a percentage change of the instruction cycle time from a base or reference value. Where the results are plotted against voltage the reference is the value at $V_{CC} = 5V$. Where the results are plotted against temperature, the reference is the value at $T = 20°C$. A positive percent variation indicates a longer instruction cycle time and therefore a slower oscillator frequency. Similarly, a negative percent variation indicates a shorter instruction cycle time and therefore a faster oscillator frequency.

The measurements were taken by holding the RESET pin of the device low and measuring the period of the waveform at pin SK. In this mode the SK period is the instruction cycle time. For divide by 4 the oscillator frequency is given by the following:

$$\text{frequency} = \frac{4}{\text{SK period}}$$

Measurements were taken at temperatures between −40°C and +85°C and at V_{CC} values between 4.5V and 9.5V. However, the reader must remember that the COP400 series is specified only between 0°C and +70°C. The reader must also remember that the COP420 is specified at V_{CC} levels between 4.5V and 6.3V only. The data here is usable for the COP300 series, which is specified at the extended temperature range of −40°C to +85°C. However, the reader must keep in mind the generally more restricted V_{CC} range for some of the various COP300 series microcontrollers.

The graphs in *Figures 1* through *6* reflect the variation of the microcontroller only. The resistor and capacitor were not in the temperature chamber with the COPS device. Obviously, the results will be affected by the variation of the R and C with temperature. However, this can vary dramatically with the type of components used. The user will have to combine the data here with the characteristics of the external components used to determine what type of variation may be expected in his system.

3.0 CRYSTAL OR INVERTER OPTION

With the crystal or inverter option selected on the COPS microcontroller there is, effectively, an inverter between the CKI and CKO pins. CKI is the input to the inverter and CKO is the output. Various passive circuits were connected between CKI and CKO and the results documented. Of the operational circuits, a subset was tested over temperature with the microcontroller only in the temperature chamber. A smaller subset was tested over temperature with both the microcontroller and the oscillator network in the temperature chamber.

The data with the oscillator network in the temperature chamber is obviously highly dependent on the particular components used. This data was taken with standard, inexpensive, uncompensated components. Neither high precision nor high stability components were used. This data is included only to provide the user with some very general indication of how the oscillator frequency may vary with temperature in a real system.

3.1 COP420/COP402

Except for the ROM, the COP420 and COP402 are equivalent devices. The internal circuitry of each device is identical. Therefore, data taken for one of the devices is equally

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applicable to the other. The following discussion will refer to the COP420 but all such references apply equally well to the COP402. Similarly, the graphs for the COP420 apply to the COP402 and *vice versa*.

With the crystal option selected, the COP420 oscillator circuitry will readily oscillate with almost any circuit configuration between CKI and CKO. What difficulty there is lies in finding the network of the device. With the appropriate divide option selected, oscillator frequencies between 800 kHz and 4 MHz are valid for the COP420. No data was taken for any network that produced an oscillation frequency outside the valid range.

3.1.1 L, LC, and RLC Networks

Various L, LC, and RLC networks were connected with varying results. Certain networks produced results much more stable than the RC networks; others were no better than the RC networks. With a single inductor connected between CKI and CKO, frequencies between 1 MHz and 4 MHz were easily obtained. However, the input gate capacitance at CKI (typically 5 pF to 10 pF) and the series resistance of the inductance become factors that impact the oscillation frequency and its stability over temperature.

The addition of a capacitor between CKI and ground tends to reduce the effects of the internal gate capacitance. For the single L, single C network of this type, the capacitor value should be greater than about 50 pF to begin to effectively swamp out the effects of the input gate capacitance. As might be expected, LC combinations which had their resonant frequencies within the valid COP420 frequency range produced the best results.

The addition of another capacitor(s) to the basic two-component LC network, as shown in *Figure III.1*, produced very good results. Varying the capacitor values in these networks — especially those capacitors between CKI and ground and CKO and ground — provided a great deal of control over the oscillation frequency. In *Figure III.1*, varying C1 from 25 pF to 0.01 μF produced oscillation frequencies between about 3 MHz and 1.6 MHz (C2 = 25 pF, L = 56 μH). In *Figure III.2*, with C1 = 330 pF, L = 56 μH, and C2 = 27 pF, varying C3 between 10 pF and 0.003 μF produced oscillation frequencies between about 2 MHz and 1.1 MHz. Varying C2 in *Figure 111.3* produced a similar kind of control.

As the graphs indicate, various types of RLC networks were also tried. The range of possible usable circuits here is limited only by the user's imagination and his favorite type of RLC oscillator circuit. When their resonant frequency is within the valid frequency range of the COP420, LC and RLC networks can be a very effective substitute for a crystal. The only potential problem is that a good RLC, or even LC, oscillator circuit may not be a cost-effective substitute for a crystal in a COP420 system. The user will have to make that determination.

3.2 COP420L

The valid input frequency range for the COP420L, with the appropriate divide option selected, is between 200 kHz and 2.097 MHz. With the crystal option selected the COP420L oscillated much less readily than the COP420.

The LC networks gave outstanding results with the COP420L. With the simple two-component LC network shown in the graphs, holding C at 50 pF and varying L from 200 μH to 700 μH gave oscillation frequencies from about 2 MHz to 1 MHz. Holding L at 390 μH and varying C from 10 pF to 700 pF gave oscillation frequencies of about 2 MHz to 1.6 MHz. Similar results were obtained when a capacitor was placed in parallel with the inductance.

3.3 COP410L

The COP410L has a valid input frequency range of 200 kHz to 530 kHz.

The LC networks also gave very good results. With the simple LC network shown in the graphs, holding L at 4700 μH and varying C from 25 pF to 0.003 μF gave oscillation frequencies of about 460 kHz to 225 kHz.

3.4 GENERAL NOTES

With the crystal or inverter option selected on COPS microcontrollers, a wide variety of networks may be used in place of the ceramic resonator or crystal.

LC and RLC networks can be used in any of the devices. Appropriately designed, these networks will provide a stable oscillation frequency for the microcontroller. The user will have to allow for the variation of the external components with temperature when using these networks. The problems with networks such as these is that they may not be cost-effective alternatives to the crystal or resonator, especially if high stability, temperature compensated components are used. The user will have to make the determination of cost-effectiveness.

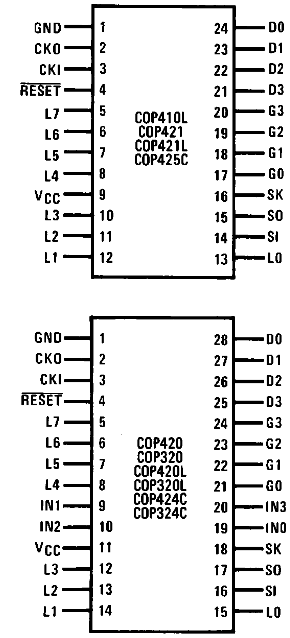
A final note is that all of these networks place a load on the CKO output. If the signal from CKO is needed elsewhere in the system and a circuit similar to one of those discussed in this document is used, it will probably be necessary to buffer the CKO output.

4.0 Conclusion

The networks described are generally simple and inexpensive and have all been observed to be functional.

The results obtained provide greater flexibility in the oscillator selection in a COPs system and gives the user some general indication as to what may be expected with the various circuits described.

COP Microcontroller Pinouts



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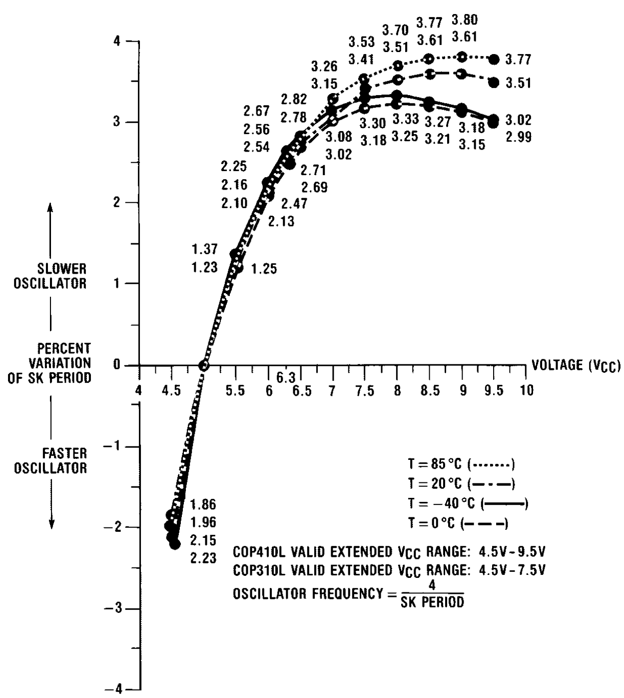


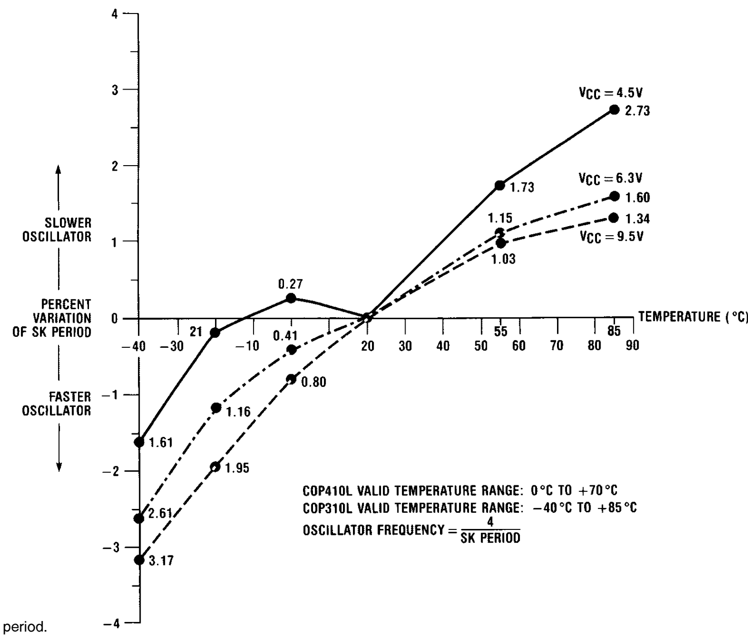
TL/DD/6938–2

Note 1: Base period at V_{CC} = 5.0V.

Note 2: Device variation only. Graph does not include RC variation with temperature.

Note 3: SK period = instruction cycle time.

FIGURE 1. COP310L/COP410L RC Oscillator Variation with V_{CC}



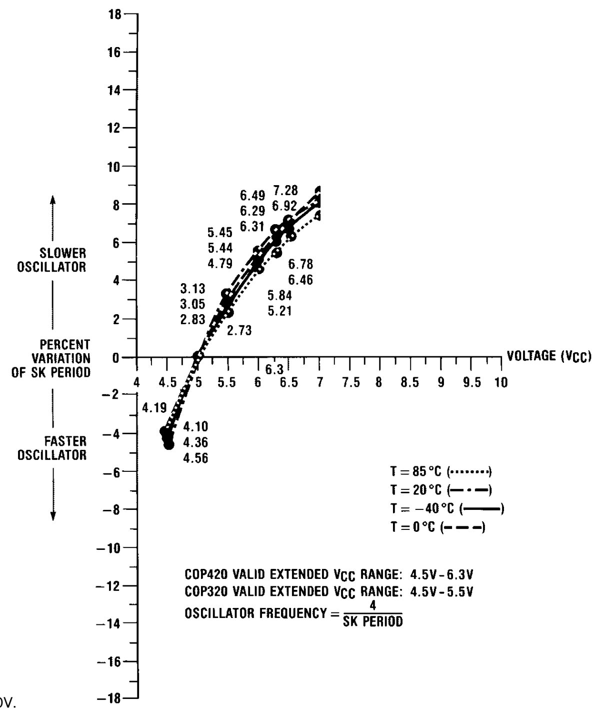
Note 1: 20°C = base period.

TL/DD/6938–3

Note 2: Device variation only. Graph does not include RC variation with temperature.

Note 3: SK period = instruction cycle time.

FIGURE 2. COP310L/COP410L RC Oscillator Variation with Temperature



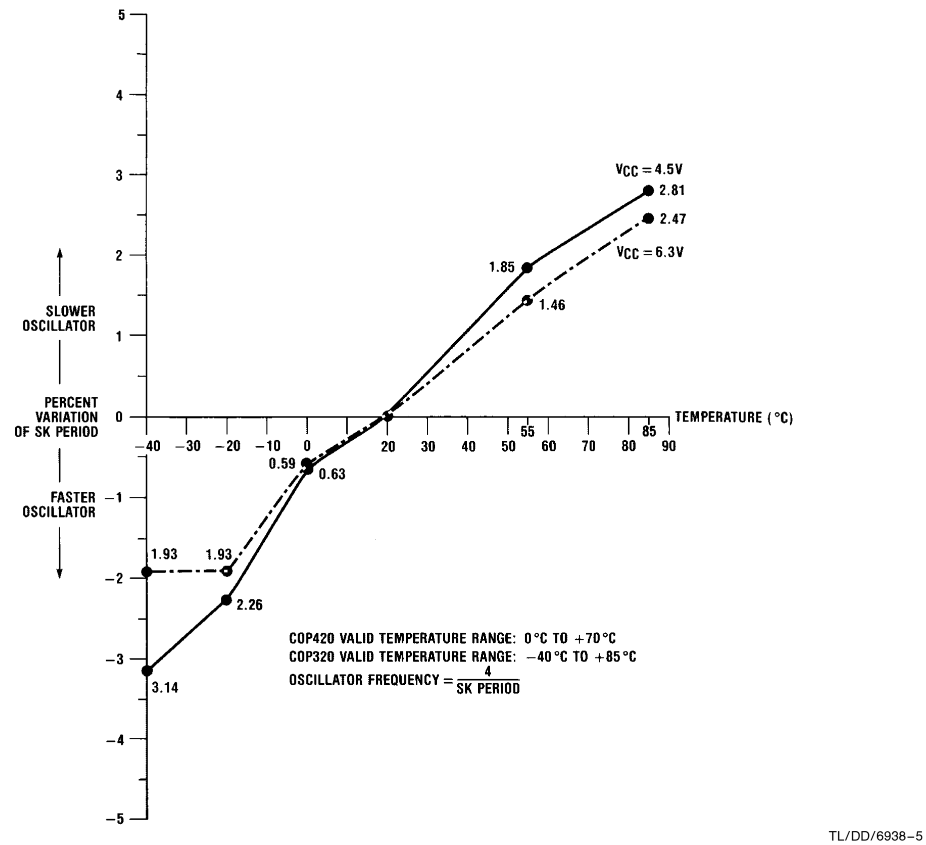
Note 1: Base period at V_{CC} = 5.0V.

TL/DD/6938–4

Note 2: Device variation only. Graph does not include RC variation with temperature.

Note 3: SK period = instruction cycle time.

FIGURE 3. COP320/COP420 RC Oscillator Variation with V_{CC}

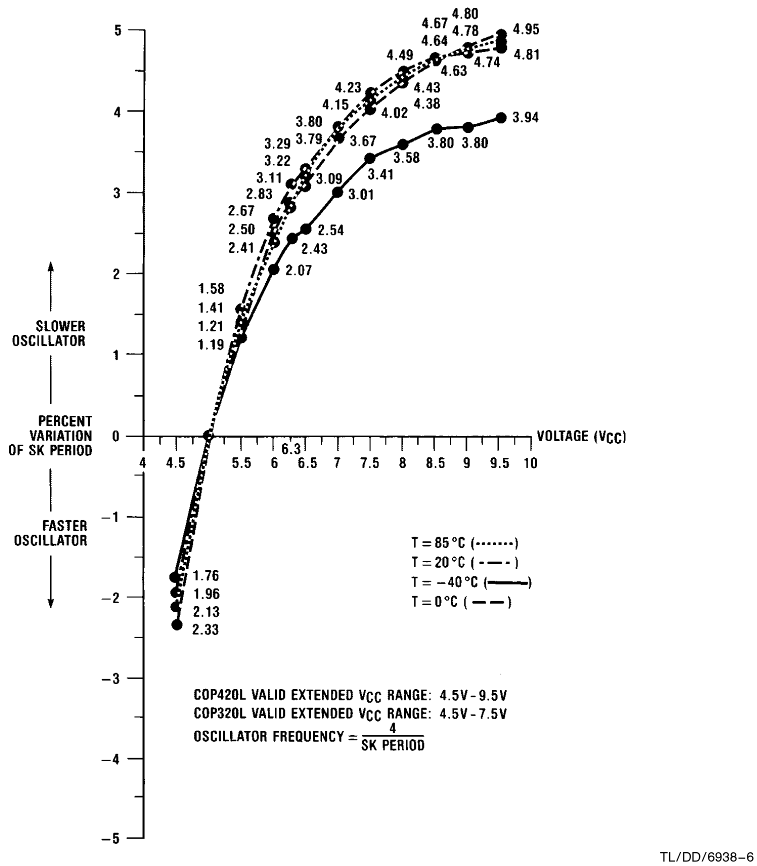


Note 1: 20°C = base period.

Note 2: Device variation only. Graph does not include RC variation with temperature.

Note 3: SK period = instruction cycle time.

FIGURE 4. COP320/COP420 RC Oscillator Variation with Temperature

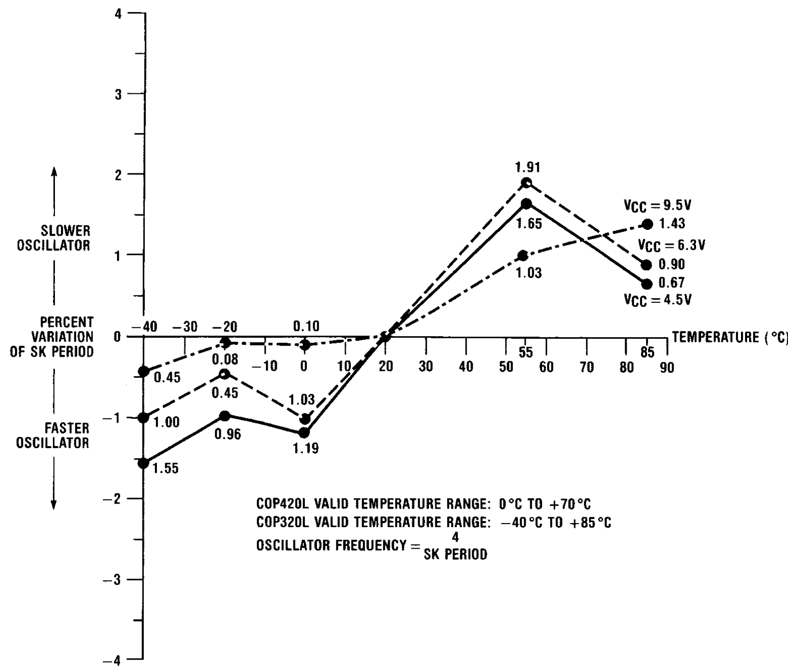


Note 1: Base period at V_{CC} = 5.0V.

Note 2: Device variation only. Graph does not include RC variation with temperature.

Note 3: SK period = instruction cycle time.

FIGURE 5. COP320L/COP420L RC Oscillator Variation with V_{CC}



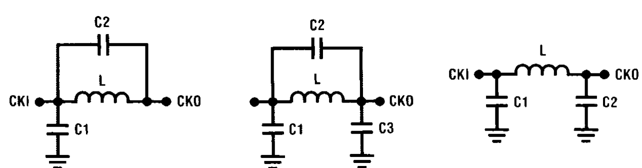
TL/DD/6938–7

Note 1: 20°C = base period.

Note 2: Device variation only. Graph does not include RC variation with temperature.

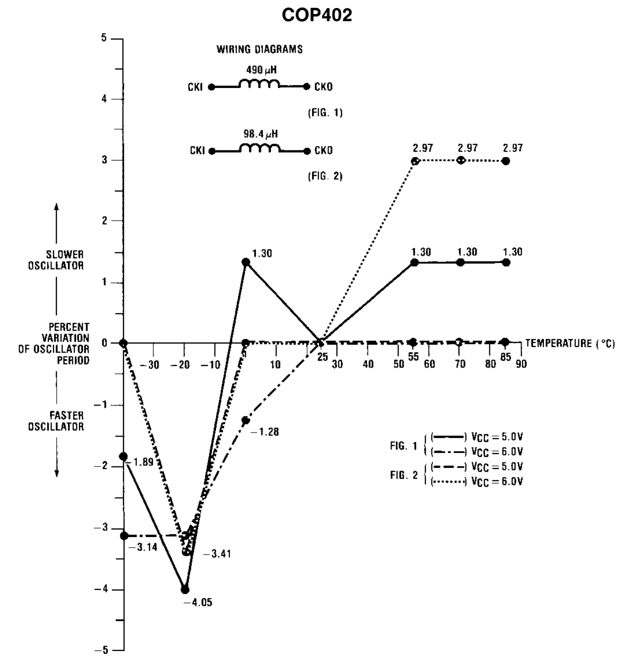
Note 3: SK period = instruction cycle time.

FIGURE 6. COP320L/COP420L RC Oscillator Variation with Temperature



TL/DD/6938–8

FIGURE III.1 **FIGURE III.2** **FIGURE III.3**

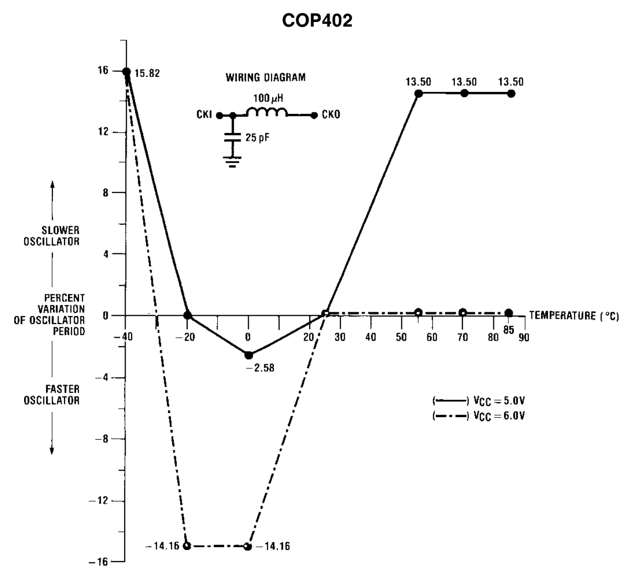


Note 1: 25°C = base period.

TL/DD/6938–9

Note 2: Device variation only. Graph does not include "L" variation with temperature.

FIGURE 7



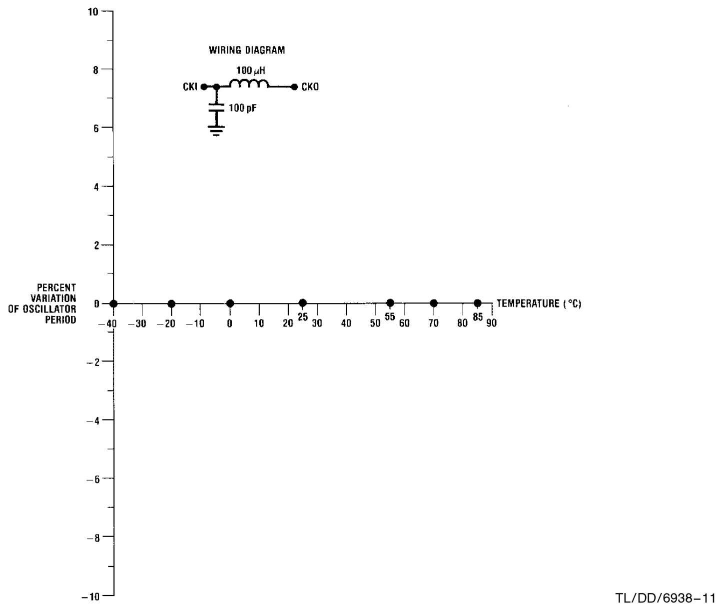
Note 1: 25°C = base period.

TL/DD/6938–10

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 8

COP420



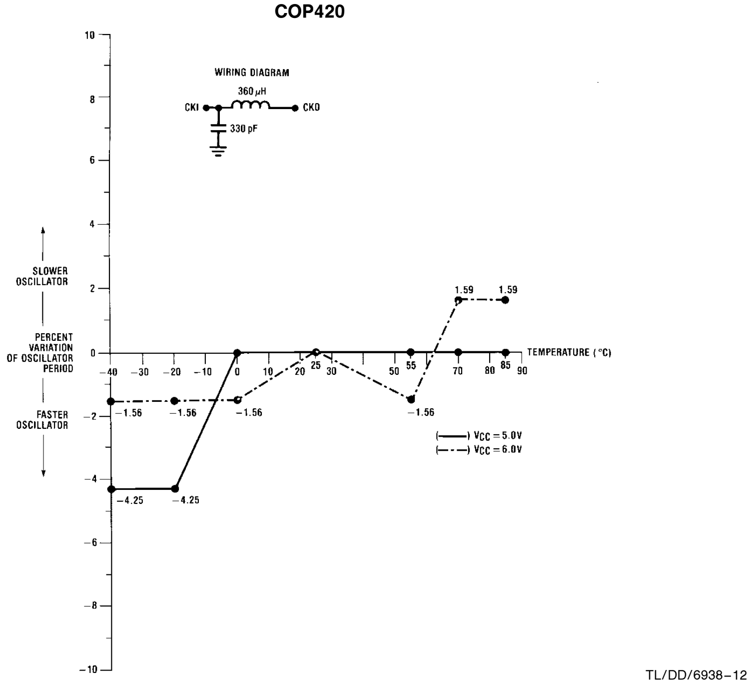
Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

No measurable variation over temperature.

FIGURE 9

COP420

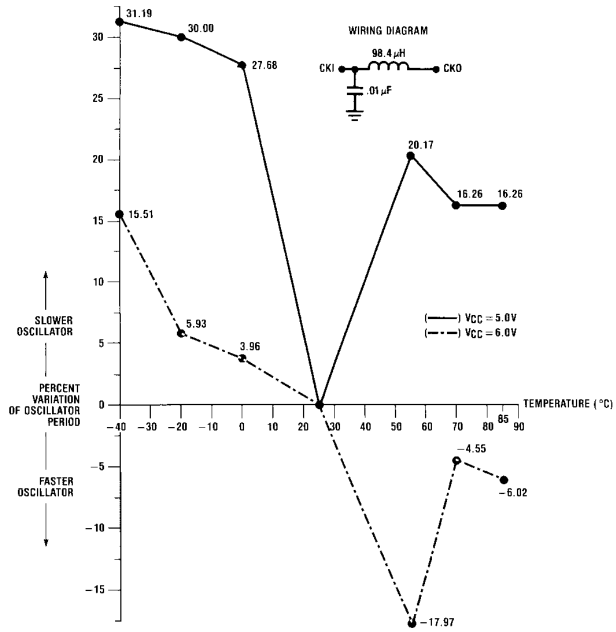


Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 10

COP402



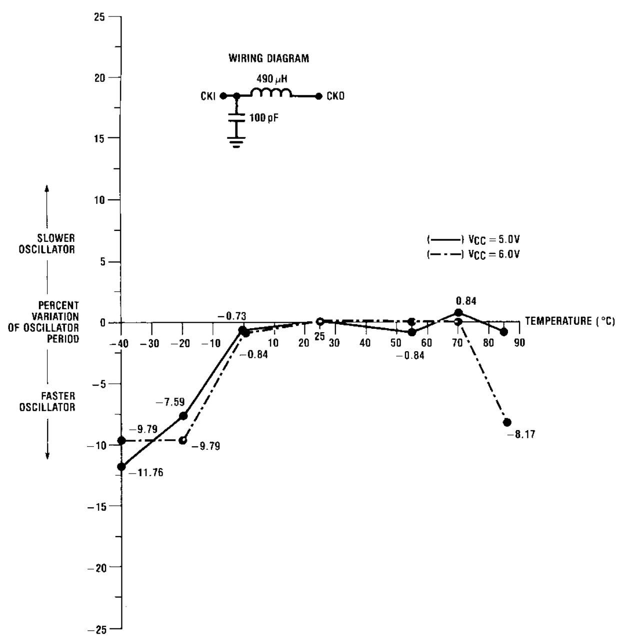
TL/DD/6938–13

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 11

COP402



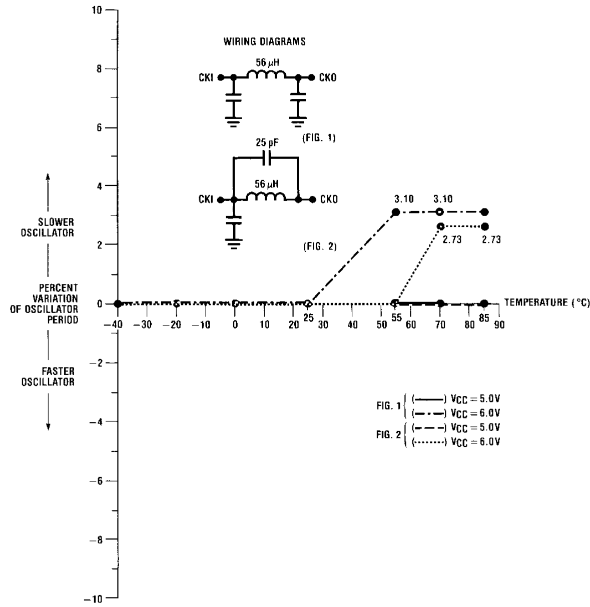
TL/DD/6938–14

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 12

COP402



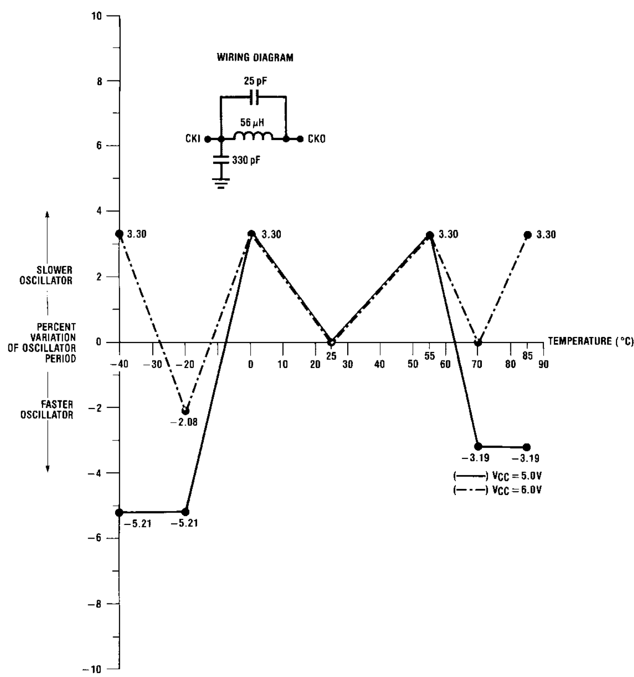
TL/DD/6938–15

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 13

COP402



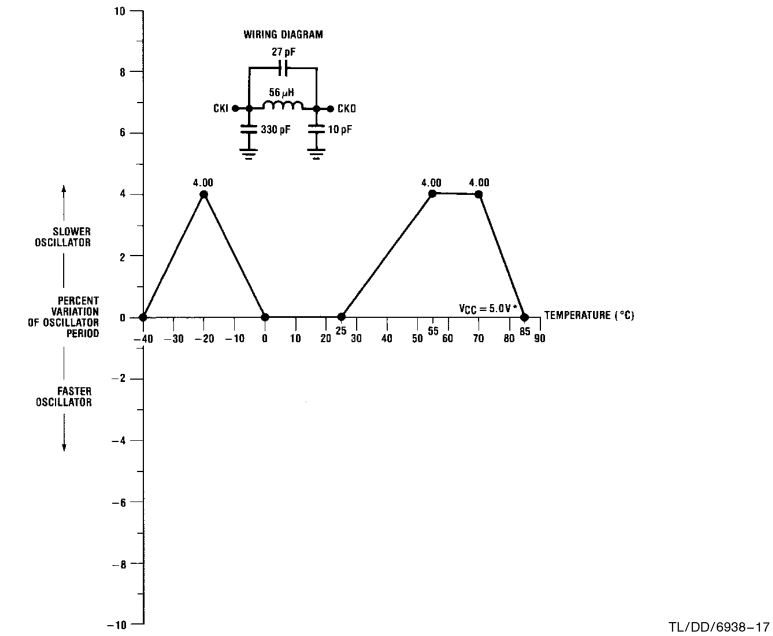
TL/DD/6938–16

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 14

COP402



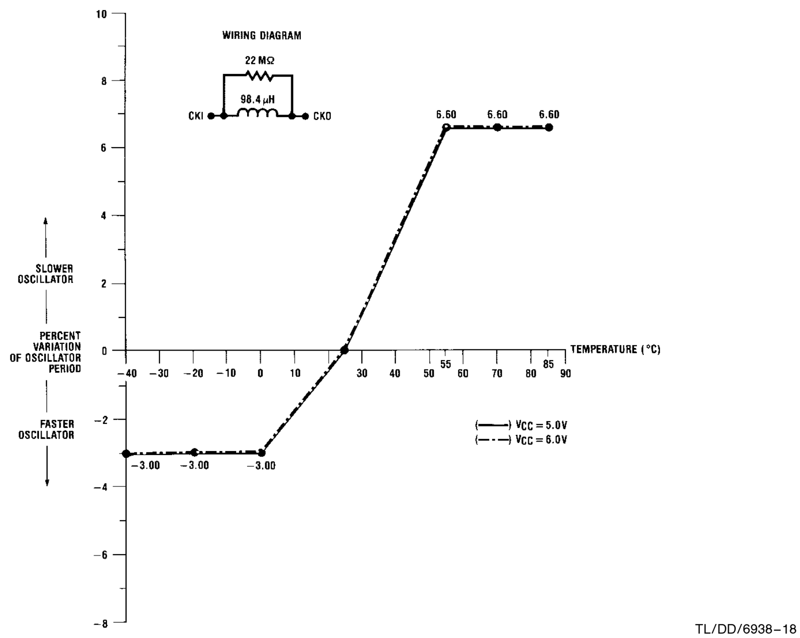
Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

*No variation at 6V.

FIGURE 15

COP402

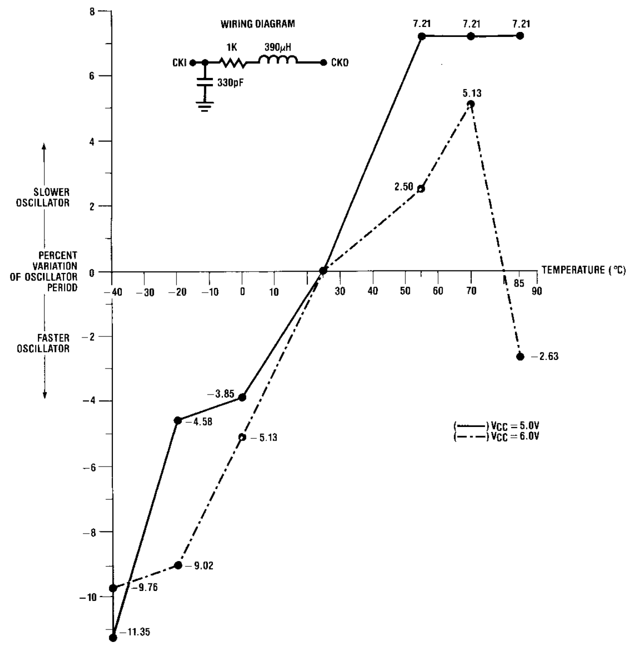


Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include RL variation with temperature.

FIGURE 16

COP402



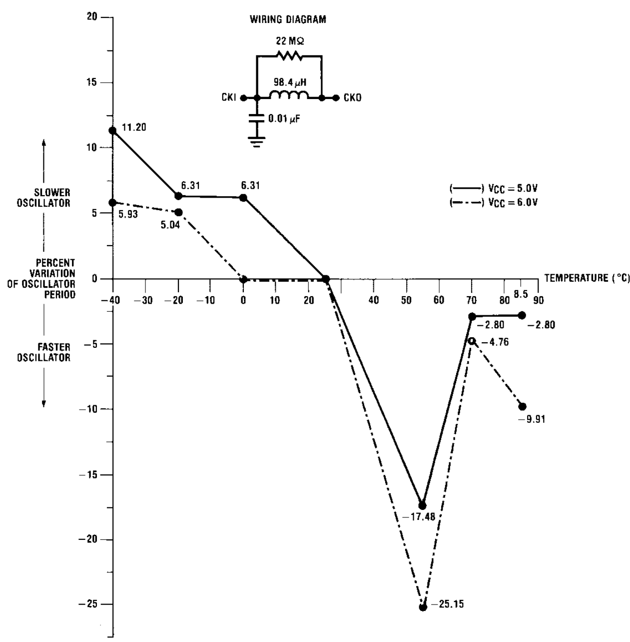
TL/DD/6938–19

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include RLC variation with temperature.

FIGURE 17

COP402



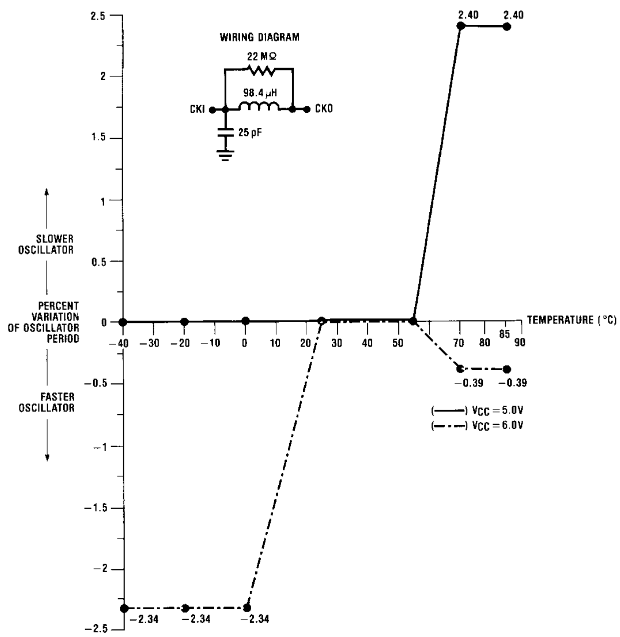
TL/DD/6938–20

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include RLC variation with temperature.

FIGURE 18

COP402



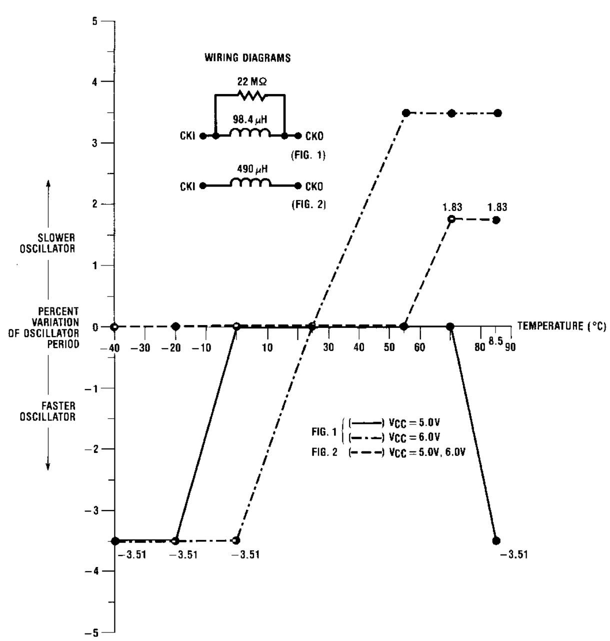
TL/DD/6938–21

Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include RLC variation with temperature.

FIGURE 19

COP402



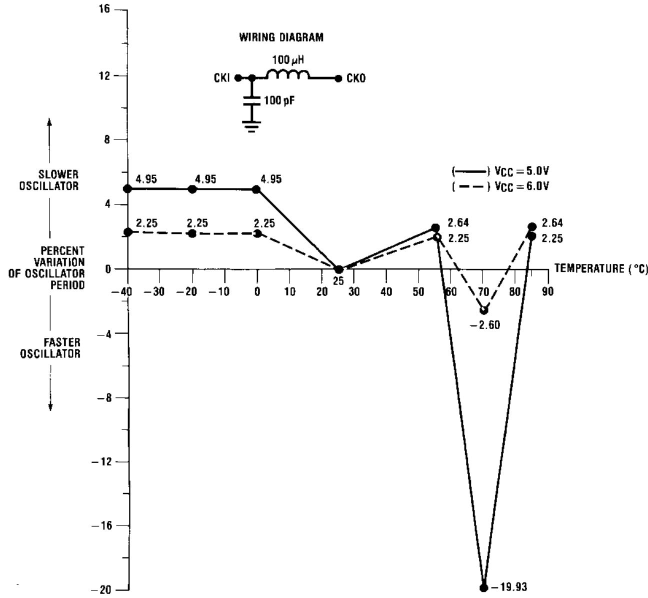
TL/DD/6938–22

Note 1: 25°C = base period.

Note 2: RL in oven with COP402.

FIGURE 20

COP420



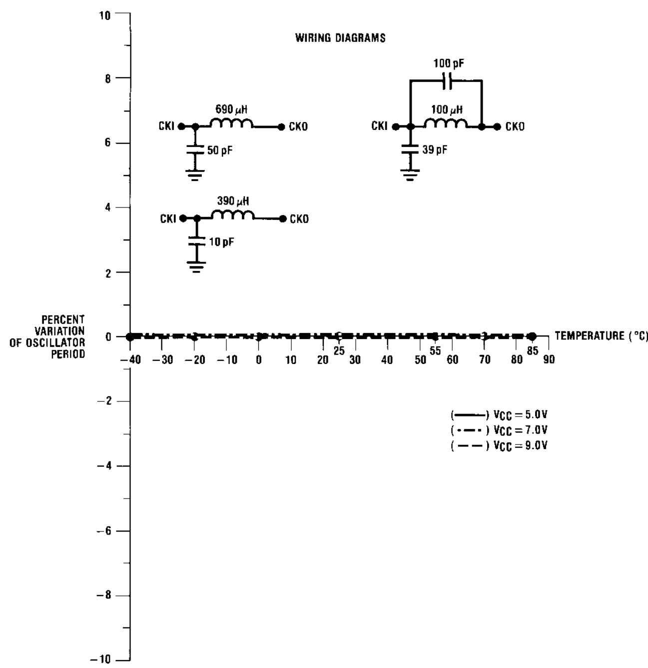
Note 1: 25°C = base period.

Note 2: LC in oven with COP402.

TL/DD/6938–23

FIGURE 21

COP420L



TL/DD/6938–26

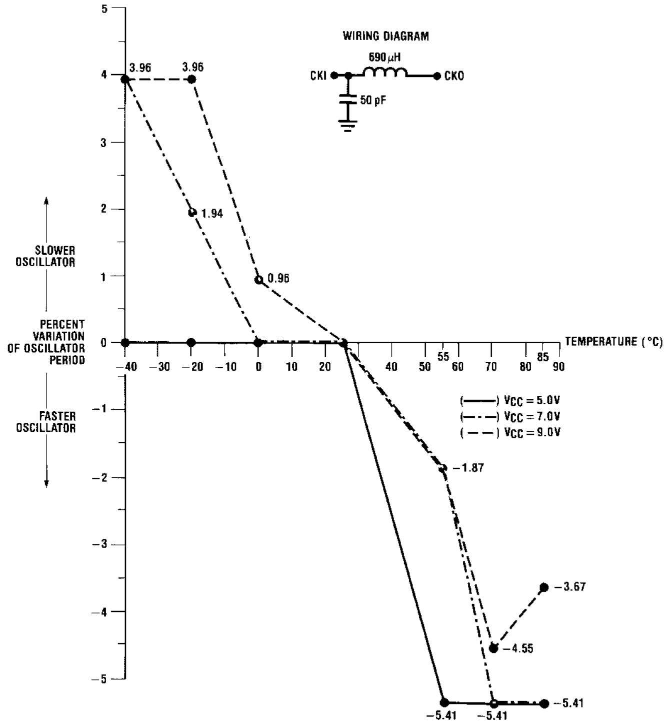
Note 1: No measurable variation for all three circuits above.

Note 2: 25°C = base period.

Note 3: Device variation only. Graph does not include LC variation with temperature.

FIGURE 22

COP420L

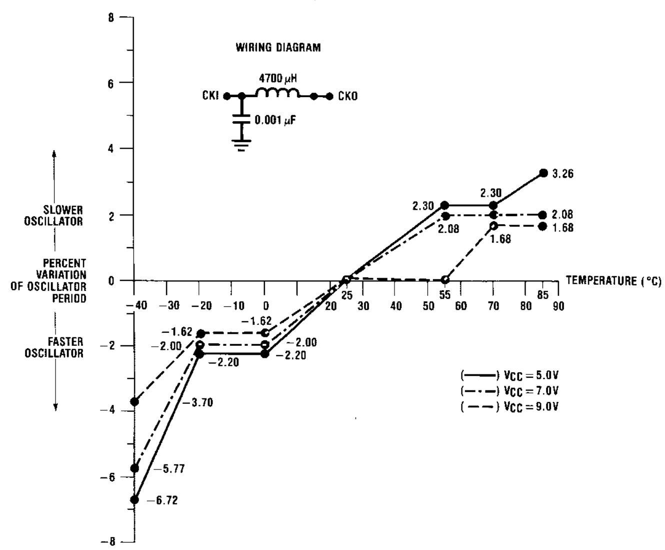


Note 1: 25°C = base period.

Note 2: LC in oven with COP420L.

FIGURE 23

COP410L

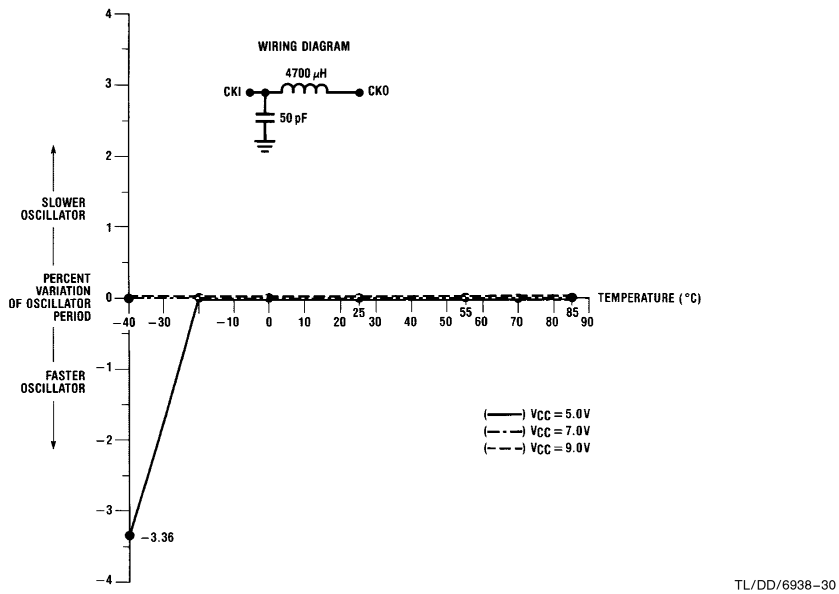


Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 24

COP410L

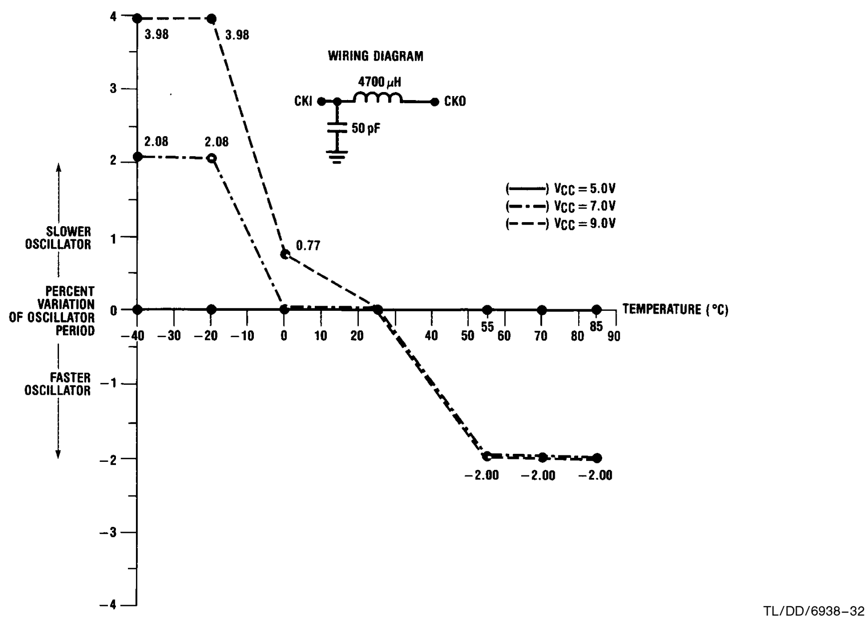


Note 1: 25°C = base period.

Note 2: Device variation only. Graph does not include LC variation with temperature.

FIGURE 25

COP410L



Note 1: 25°C = base period.

Note 2: LC in oven with COP410L.

FIGURE 26

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