How to Use the LTC6900 Low Power SOT-23 Oscillator as a VCO

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Introduction

The LTC6900 is a precision low power oscillator that is extremely easy to use and occupies very little PC board space. It is a lower power version of the LTC1799, which was featured in the February 2001 issue of this magazine.

The output frequency, f_{OSC}, of the LTC6900 can range from 1kHz to 20MHz—programmed via an external resistor, R_{SET}, and a 3-state frequency divider pin, as shown in Figure 1.

$$R_{SET} = 20k \bullet \left(\frac{10MHz}{N \bullet f_{OSC}}\right), \; N = \begin{cases} 100 \\ 10 \\ 1 \end{cases} \quad (1)$$

A proprietary feedback loop linearizes the relationship between R_{SET} and the output frequency so the frequency accuracy is already included in the expression above. Unlike other discrete RC oscillators, the LTC6900 does not need correction tables to adjust the formula for determining the output frequency.

Figure 2 shows a simplified block diagram of the LTC6900. The LTC6900 master oscillator is controlled by the ratio of the voltage between V^+ and the SET pin and the current, I_{RES}, entering the SET pin. *As long as I_{RES} is precisely the current through resistor R_{SET}*, the ratio of $(V^+ - V_{SET}) / I_{RES}$ equals R_{SET} and the frequency of the LTC6900 depends solely on the value of R_{SET}. This technique ensures accuracy, typically ±0.5% at ambient temperature.

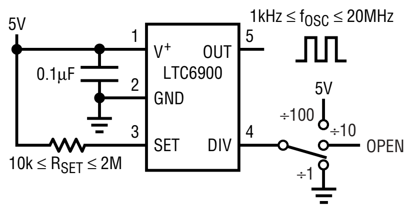

Figure 1. Basic connection diagram

As shown in Figure 2, the voltage of the SET pin is controlled by an internal bias, and by the gate to source voltage of a PMOS transistor. The voltage of the SET pin (V_{SET}) is typically 1.1V below V^+.

Programming the Output Frequency

The output frequency of the LTC6900 can be programmed by altering the value of R_{SET} as shown in Figure 1 and the accuracy of the oscillator will not be affected. The frequency can also be programmed by steering current in or out of the SET pin, as conceptually shown in Figure 3. This technique can degrade accuracy as the ratio of $(V^+ - V_{SET}) / I_{RES}$ is no longer uniquely dependent on the value of R_{SET}, as shown in Figure 2. This loss of accuracy will become noticeable when the magnitude of I_{PROG} is comparable to I_{RES}. The frequency variation of the LTC6900 is still monotonic.

Figure 4 shows how to implement the concept shown in Figure 3 by connecting a second resistor, R_{IN}, between the SET pin and a ground referenced voltage source V_{IN}.

For a given power supply voltage in Figure 4, the output frequency of the LTC6900 is a function of V_{IN}, R_{IN}, R_{SET}, and $(V^+ - V_{SET}) = V_{RES}$:

$$f_{OSC} = \frac{10MHz}{N} \bullet \frac{20k}{R_{IN} \| R_{SET}} \bullet \left[1 + \frac{(V_{IN} - V^+)}{V_{RES}} \bullet \left(\frac{1}{1 + \frac{R_{IN}}{R_{SET}}}\right)\right] \quad (2)$$

When $V_{IN} = V^+$ the output frequency of the LTC6900 assumes the highest value and it is set by the parallel combination of R_{IN} and R_{SET}. Also note, the output frequency, f_{OSC}, is independent of the value of $V_{RES} = (V^+ - V_{SET})$ so, the accuracy of f_{OSC} is within the datasheet limits.

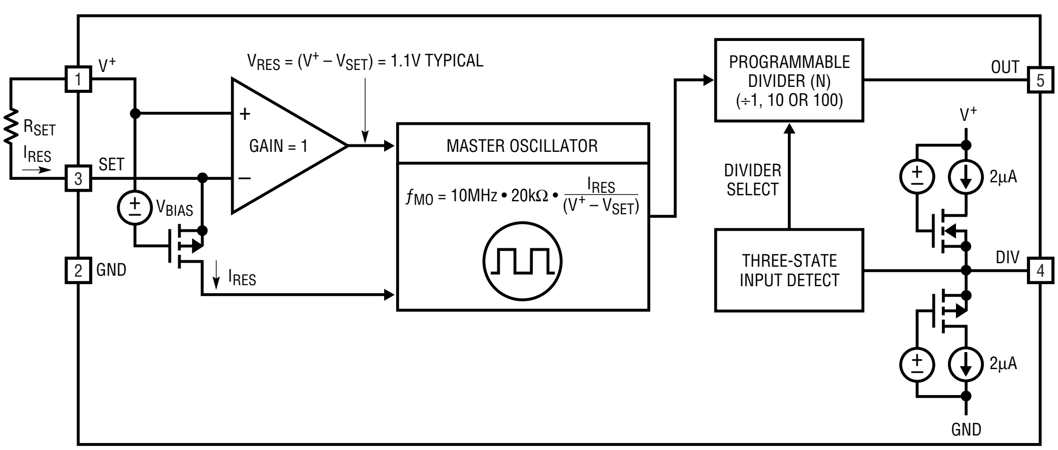

Figure 2. Simplified block diagram

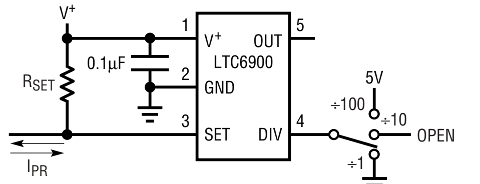

Figure 3. Concept for programming via current steering

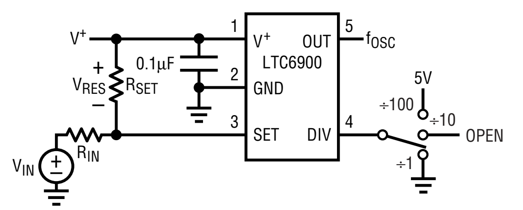

Figure 4. Implementation of the concept shown in Figure 3

When V_{IN} is less than V^+, and especially when V_{IN} approaches the ground potential, the oscillator frequency, f_{OSC}, assumes its lowest value and its accuracy is affected by the change of $V_{RES} = (V^+ - V_{SET})$. At 25°C V_{RES} varies by ±8%, assuming the variation of V^+ is ±5%. The temperature coefficient of V_{RES} is 0.02%/°C.

By manipulating the algebraic relation for f_{OSC} above, a simple algorithm can be derived to set the values of external resistors R_{SET} and R_{IN}, as shown in Figure 4:

1. Choose the desired value of the maximum oscillator frequency, $f_{OSC(MAX)}$, occurring at maximum input voltage $V_{IN(MAX)} \le V^+$.
2. Set the desired value of the minimum oscillator frequency, $f_{OSC(MIN)}$, occurring at minimum input voltage $V_{IN(MIN)} \ge 0$.
3. Choose $V_{RES} = 1.1$ and calculate the ratio of R_{IN}/R_{SET} from the following:

$$\frac{R_{IN}}{R_{SET}} = \frac{\left(V_{IN(MAX)} - V^+\right) - \left(\frac{f_{OSC(MAX)}}{f_{OSC(MIN)}}\right)\left(V_{IN(MIN)} - V^+\right)}{V_{RES}\left[\left(\frac{f_{OSC(MAX)}}{f_{OSC(MIN)}}\right) - 1\right]} - 1 \qquad (3)$$

Once R_{IN}/R_{SET} is known, calculate R_{SET} from:

$$R_{SET} = \frac{10MHz}{N} \bullet \frac{20k}{f_{OSC(MAX)}} \bullet \left[\frac{\left(V_{IN(MAX)} - V^+\right) + V_{RES}\left(1 + \frac{R_{IN}}{R_{SET}}\right)}{V_{RES}\left(\frac{R_{IN}}{R_{SET}}\right)}\right] \qquad (4)$$

Example 1: In this example, the oscillator output frequency has small excursions. This is useful where the frequency of a system should be tuned around some nominal value.

Let $V^+ = 3V$, $f_{OSC(MAX)} = 2MHz$ for $V_{IN(MAX)} = 3V$ and $f_{OSC(MIN)} = 1.5MHz$ for $V_{IN}=0V$. Solve for R_{IN}/R_{SET} by equation (3), yielding $R_{IN}/R_{SET} = 9.9/1$. $R_{SET} = 110.1kΩ$ by equation (4). $R_{IN} = 9.9R_{SET} = 1.089MΩ$. For standard resistor values, use $R_{SET} = 110kΩ$ (1%) and $R_{IN} = 1.1MΩ$ (1%). Figure 5 shows the measured f_{OSC} vs V_{IN}. The 1.5MHz to 2MHz frequency excursion is quite limited, so the curve f_{OSC} vs V_{IN} is linear.

Example 2: Vary the oscillator frequency by one octave per volt. Assume $f_{OSC(MIN)} = 1MHz$ and $f_{OSC(MAX)} = 2MHz$, when the input voltage varies by 1V. The minimum input voltage is half supply, that is $V_{IN(MIN)} = 1.5V$, $V_{IN(MAX)} = 2.5V$ and $V^+ = 3V$.

Equation (3) yields $R_{IN}/R_{SET} = 1.273$ and equation (4) yields $R_{SET} = 142.8kΩ$. $R_{IN} = 1.273R_{SET} = 181.8kΩ$. For standard resistor values, use $R_{SET} = 143kΩ$ (1%) and $R_{IN} = 182kΩ$ (1%).

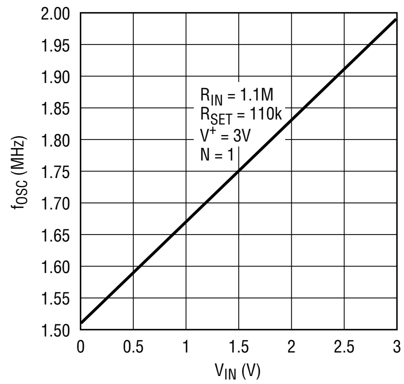

Figure 5. Output frequency vs input voltage

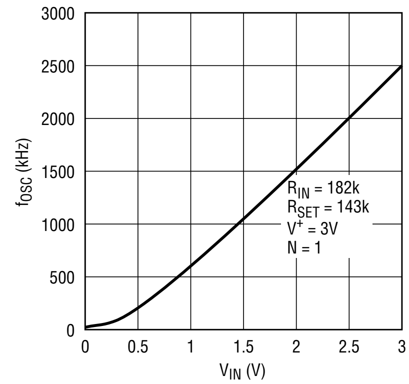

Figure 6. Output frequency vs input voltage

Figure 6 shows the measured f_{OSC} vs V_{IN}. For V_{IN} higher than 1.5V the VCO is quite linear; nonlinearities occur when V_{IN} becomes smaller than 1V, although the VCO remains monotonic.

The VCO modulation bandwidth is 25kHz that is, the LTC6900 will respond to changes in the frequency programming voltage, V_{IN}, ranging from DC to 25kHz.

Note:

All of the calculations above assume $V_{RES} = 1.1V$, although $V_{RES} \approx 1.1V$. For completeness, Table 1 shows the variation of V_{RES} against various parallel combinations of R_{IN} and R_{SET} ($V_{IN} = V^+$). Calculate first with $V_{RES} \approx 1.1V$, then use Table 1 to get a better approximation of V_{RES}, then recalculate the resistor values using the new value for V_{RES}.

Table 1: Variation of V_{RES} for various values of $R_{IN} || R_{SET}$

$R_{IN} \| R_{SET}$ ($V_{IN} = V^+$)	V_{RES}, $V^+ = 3V$	V_{RES}, $V^+ = 5V$
20k	0.98V	1.03V
40k	1.03V	1.08V
80k	1.07V	1.12V
160k	1.1V	1.15V
320k	1.12V	1.17V

V_{RES} = Voltage across R_{SET}