High Accuracy Clock up to 170MHz in a SOT-23

by Albert Huntington

Introduction

Crystal based oscillators are often the default choice for designers looking to clock today's high speed microcontrollers, data converters and programmable logic devices. Crystal oscillators, although convenient, accurate and stable, come at a high price in use—they occupy considerable board space, consume significant power, and are sensitive to environmental factors like shock and temperature extremes. The LTC6905 is an all silicon clock that avoids these pitfalls, making it an alternative to crystal oscillators in applications up to 170MHz.

Accuracy and jitter specifications of the LTC6905 are more than sufficient for most applications, and its power and size advantages allow the LTC6905 to fit in designs where a crystal oscillator could never go.

Device Description

The LTC6905 is a part of Linear Technology's line of resistor controlled SOT-23 oscillators. These resistor controlled oscillators use a single external resistor to accurately set the oscillator frequency, and there is a simple linear relationship between the resistor value and the frequency (see Figure 1). The LTC6905 is pin-compatible with the LTC1799 SOT-23 oscillator, but uses a different control resistor range and a different formula to set the frequency.

The LTC6905 is also available in fixed frequency versions, where the resistor is internal to the part and no external components other than a bypass capacitor are required. Preset devices with master oscillator frequencies of 133MHz, 100MHz, 96MHz and 80 MHz and 1.5% accuracy are available. These devices have an internal divider which makes it possible to produce most popular frequencies between 20MHz and 133MHz. Devices can be customized to output any frequency in the range of 2.2MHz to 170Mhz.

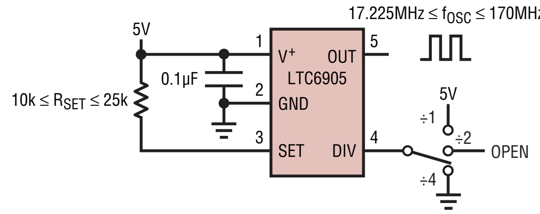

Figure 1. A single resistor sets the frequency of this tiny, robust oscillator.

The LTC6905 uses an internal feedback loop to accurately match the impedance of a switched capacitor element to the external resistor connected to the R_{SET} pin, thus setting the master oscillator frequency. The voltage level on the DIV pin engages internal dividers to divide this master frequency by 1, 2 or 4 before it is sent to the OUT pin. With fixed frequency devices, the LTC6905-XXX series of parts, the RSET pin is replaced by an output enable pin, which disables the output when it is connected to GND.

The voltage on the R_{SET} pin of the LTC6905 is forced to a bandgap controlled voltage of 1V below the positive supply, independent of the temperature or supply voltage, with a tolerance of less than 5%. This stable R_{SET} voltage makes the LTC6905 ideal for applications where an accurate voltage or current controlled frequency is required.

The frequency range of the master oscillator in the LTC6905 is limited to between 70MHz and 170MHz, which corresponds to external frequency setting resistor values between 10kΩ and 25kΩ. This range is expanded by the internal dividers to between 17MHz and 170MHz, and is limited by the architecture of the high speed master oscillator.

The master oscillator of the LTC6905 is a voltage controlled ring oscillator, and provides a unique jitter profile where the jitter percentage remains relatively constant over frequency. Traditional relaxation oscillators develop a larger percentage jitter as the frequency increases. The jitter of the LTC6905 actually decreases with increasing operating frequency, making it ideal for high frequency applications.

Fixed Frequency Devices

The LTC6905 can be ordered in a fixed frequency version where the frequency-setting resistor is inside the part. An output enable pin is made available in place of the R_{SET} pin on these devices only. Four versions are available: LTC6905-133, LTC6905-100, LTC6905-96 and LTC6905-80. These four versions collectively offer 12 popular frequencies through the use of their DIV pins. Please see Table 1.

The LTC6905-XXX fixed frequency oscillators offer several advantages that stem from their internal resistor configuration. The parts are less sensitive to external noise that may couple into the R_{SET} pin on the external resistor version of the part. This lack of sensitivity translates into improved jitter of less than 1% at all frequencies and accuracy of better than 1.5% over commercial temperature range. The internal resistor parts are generally more accurate because they are trimmed at one specific frequency and do not have any error term from nonlinearities over the R_{SET} resistor range.

The absence of an R_{SET} pin on the fixed-frequency devices has made room for an output enable pin. This output enable synchronously disables the output drivers when brought low,

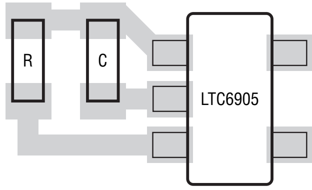

Figure 2. LTC6905 Suggested layout. Note that the bypass capacitor is located adjacent to the device and on the same side of the PC board.

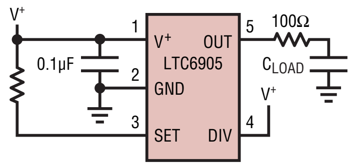

Figure 3. A series resistor on the LTC6905 output pin reduces power supply spikes caused by load capacitance.

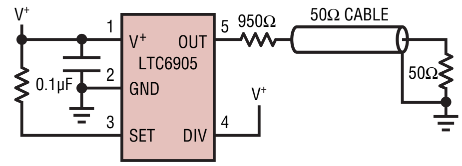

Figure 4. The LTC6905 can drive a 50Ω cable with appropriate termination.

and does not produce pulse slivers. Power dissipation is significantly reduced because much of the power is dedicated to driving output capacitance. The internal master oscillator and bias networks remain active in order to facilitate an immediate and accurate frequency output when the output is enabled. If the output enable pin is left floating or pulled to the positive supply, the oscillator is enabled.

Layout Considerations

Because the LTC6905 combines a high frequency oscillator and output stage with a sensitive analog control loop, it is necessary to exercise great care in board layout to maximize accuracy and stability. The bypass capacitor must be placed as close as possible to the LTC6905, preferably on the same side of the board. Even the small inductance and resistance of vias in the pc board can adversely effect part performance. Additionally, the traces to the bypass capacitor should be larger than is indicated by the power consumption of the device. Although the average power consumption is low, driving a capacitively loaded output will induce spikes in the supply current which must be damped by the bypass capacitor.

The R_{SET} pin is the most sensitive input pin, and attempts must be made to shield it from noise coupling or excessive parasitic capacitance. It is recommended that the frequency setting resistor be located as close as possible to the R_{SET} pin, and that the frequency setting resistor be connected to the positive supply as close as possible to the V^+ pin. A recommended layout is illustrated in Figure 2. If the bypass capacitor must be situated on the opposite side of the PC board from the LTC6905, it is strongly recommended that the connection between the capacitor and the LTC6905 be as short as possible and use multiple, filled vias to minimize series inductance and resistance.

The LTC6905 is specified at an output load of 5pF, which is equivalent to about two standard HC logic inputs. Driving this load at 170MHz is the single largest factor in the power consumption of the LTC6905. The power supply current needed to drive a capacitive load may be calculated as:

$$I_{SUPPLY} = C_{LOAD} \bullet V_{SWING} \bullet F_{OSC}$$

where C_{LOAD} is the 5pF load capacitance, V_{SWING} is the voltage swing, in this case up to 5.5V, and F_{OSC} is the frequency of the oscillator. Driving a 5.5V swing into a 5pF load at 170MHz takes 4.675mA on average.

The majority of this power is expended during the risetime and falltime of the output signal, not while it is in a steady state. The 500ps rise and fall times of the LTC6905 mean that the instantaneous power supply current required during the rise and fall portions of the waveform is much greater than the average. The instantaneous power supply current may be calculated by a similar formula:

$$I_{PEAK} = C_{LOAD} \times V_{SWING} \times \frac{1}{t_{rf}}$$

where t_{rf} is the rise/fall time of the signal. In this case, 55mA spikes are generated by driving 5.5V into a 5pF load.

Because of these power supply spikes, and because of the tendency for fast edges to couple into adjacent lines, the layout of the output trace is critical. Capacitance, trace length and loading should be minimized. Additionally, with traces longer than a few centimeters, transmission line effects must be taken into consideration.

Should output loading and coupling problems occur, there are methods to mitigate the effects. A series resistance in the range of 50Ω–1000Ω placed adjacent to the output pin of the device will increase the rise and fall times of the signal being driven into the output load, and therefore reduce power supply spikes and coupling (see Figure 3). A 50Ω cable may be driven using a 950Ω series resistance and a 50Ω termination to ground, though the signal will be attenuated (see Figure 4). A high speed comparator or inexpensive AHC series CMOS logic gate may be placed in the signal path directly after the LTC6905 in order to buffer the output signal and drive heavier loads.

Voltage and Current Controlled Oscillators

The LTC6905 is an ideal candidate for making a voltage or current controlled oscillator. Unlike other resistor controlled parts, where the voltage on R_{SET} varies with power supply and temperature, the LTC6905 maintains

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Table 1. LTC6905 family fixed frequency oscillators

DIV Setting	LTC6905-133	LTC6905-100	LTC6905-96	LTC6905-80
V+ (÷1)	133.33MHz	100 MHz	96 MHz	80 MHz
OPEN (÷2)	66.66MHz	50MHz	48MHz	40MHz
GND (÷4)	33.33MHz	25MHz	24MHz	20MHz

Low Noise, Synchronous Step-Up DC-DC Converter Connects V_{OUT} to V_{IN} in Shutdown

The LTC3400-1 is an efficient and tiny synchronous step-up DC-DC converter that provides a direct connection from output to input when shut down. This feature is useful in products where the battery power source needs to be monitored while the converter is turned off, or to provide a path for backup power from the main battery.

The LTC3400-1 is pin-for-pin compatible with the LTC3400 family of synchronous step-up regulators. Like the LTC3400 family, it can operate from a single-cell alkaline battery input up to 4.5V and features power conversion efficiency up to 95%. The internal switch and synchronous rectifier are rated at 600mA (min). The output voltage can be programmed from 2.5 to 5.0V with an external resistor divider. The 1.2MHz fixed frequency architecture provides very low V_{OUT} ripple, making it compatible with sensitive measurement applications, and it allows the use of a tiny, low profile inductor and ceramic input and output capacitors.

The LTC3400-1 automatically switches to Burst Mode operation at light loads to reduce battery drain. The current mode PWM architecture of the LTC3400-1 is internally compensated, reducing external parts count. Shutdown quiescent current is less than 1µA.

16-Bit DAC with I^2C Interface in a 3mm × 3mm Footprint

The LTC2606 reduces the size and improves performance of compact portable products by integrating a high performance voltage output 16-bit DAC in a 3mm × 3mm 10-pin DFN package. The LTC2606 is ideal for space-constrained applications optimizing board layout. The device's guaranteed monotonic performance is ideal for digital calibration, trim/adjust and level setting applications in a wide variety of products.

The LTC2606's output buffer has excellent drive capability over its entire 2.7V to 5.5V supply voltage range. The DAC output can directly drive capacitive loads up to 1000pF and current loads up to 15mA while maintaining good linearity to within millivolts of both supply rails. The low output offset (9mV max) provides a zero-scale voltage closer to 0V than competitive devices. Low power consumption (270µA supply current and 1µA max shutdown current) makes the LTC2606 ideal for battery-powered applications. The low output noise (15 μV_{P-P} over 0.1Hz to 10Hz) reduces the need for output filtering and is much lower than competitive devices.

The LTC2606 uses a 2-wire I^2C serial digital interface that is compatible with both the standard-mode (100kHz max clock speed) and fast-mode (400kHz max clock speed) of operation with 27 selectable I^2C slave addresses, which minimizes address conflicts with other I^2C components in the system. The device features an asynchronous update pin ($\overline{LDAC}$), which allows the DAC update to be synchronized to a hardware signal. It also allows simultaneous updates and power-up of multiple DACs in a system. A power-on reset sets the LTC2606 to zero-scale on power-up.

The LTC2606 is one of many pin compatible devices in a family of compact DACs, yielding multiple performance options from one design. The LTC2616 and LTC2626 are pin compatible 14-bit and 12-bit DACs; the LTC2606-1, LTC2616-1 and the LTC2626-1 are pin compatible 16-bit, 14-bit and 12-bit DACs which power-up at mid-scale.

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the voltage at the R_{SET} pin at 1V below the positive supply. Because the frequency of oscillation is based on the resistance, or V/I at the R_{SET} pin, a stable V at the R_{SET} pin provides the ability to generate an accurate output frequency by injecting an accurate current (I) at the R_{SET} pin.

For stability reasons, it is recommended that the R_{SET} pin be driven by resistors as shown in Figure 5. All modulation of the frequency, whether by voltage or current, relies on modulation of the current input to the R_{SET} pin. Because the R_{SET} voltage is fixed at 1V, the frequency of the output depends to the first degree only on the current into the R_{SET} pin. The master oscillator frequency may be approximated as:

$$F_{OSC} = \frac{10k\Omega}{R_{SET}} \times 170MHz$$

Substituting V_{RSET}/I_{RSET} for R_{SET}, where V_{RSET}=1V, we get:

$$F_{OSC} = 10k\Omega \times I_{RSET} \times 170MHz$$

This indicates that a 50µA current into the R_{SET} pin would result in a master oscillator frequency of 85MHz. More applications circuits and information regarding using the LTC6905 as a VCO is available in the data sheet.

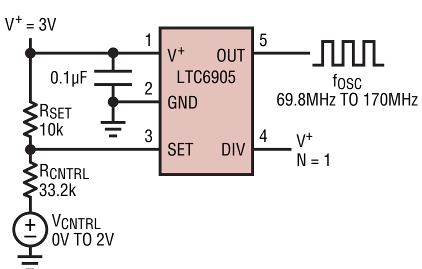

Figure 5. The LTC6905 as a voltage controlled oscillator

The modulation bandwidth of the LTC6905 is dictated by its internal control loop, which is limited to between 700kHz and 2MHz, depending on output frequency. Due to the low modulation bandwidth in relation to the output frequency, it is recommended that the LTC6905 be used as a VCO only in applications where the rate of modulation is less than the output frequency divided by 128.

Conclusion

The LTC6905 and LTC6905-XXX are low power, highly accurate silicon oscillators that can replace crystals in many applications. They offer advantages of lower cost, lower sensitivity to temperature and shock, and ease of frequency modulation—important features in driving microcontrollers, FPGAs and other complex systems.