Silicon Oscillators

High Performance Analog Solutions from Linear Technology

When was the last time you considered replacing a crystal oscillator with another clock device? In all likelihood, the answer is "never," and for good reason. After all, what performs like a crystal? The answer may surprise you.

At the heart of most clock circuits are crystal or ceramic resonators. These tried and true components boast excellent accuracy and stability, but their downside lies in their mechanical operation. As such, they are subject to wear-out, and physical impact can induce errors in the output frequency and phase. Vibration and temperature extremes can damage them and because they rely on a tuned circuit with a matched driver, they don't always start up as planned or oscillate at the intended frequency. Even the same device can start up differently from one power up cycle to the next.

An alternative to resonator-based clocks is RC-based clocks, which rely on the time-constant set by a resistor and capacitor. These are simple and more adjustable than fixed frequency crystal or ceramic devices, but poor accuracy and stability limit their usefulness.

Now there is another choice, a full family of silicon-based oscillators from Linear Technology.

A New Generation of Clock Devices

Just as vacuum tubes, relays and core memory were transformed by solid-state technology, silicon-based oscillators are beginning to displace traditional crystal and ceramic clock circuits. These devices do not rely on mechanical resonating elements and are not plagued by the poor performance of RC-based circuits. Standard silicon fabrication and assembly means inherent immunity to shock, vibration and wear-out. Start up is consistent and fast. In addition, these parts exhibit excellent accuracy, jitter, a small footprint, low power and operation from -40°C to 125°C. Linear Technology's oscillator family covers the frequency range from 1kHz to 170MHz, including both fixed and programmable frequency devices.

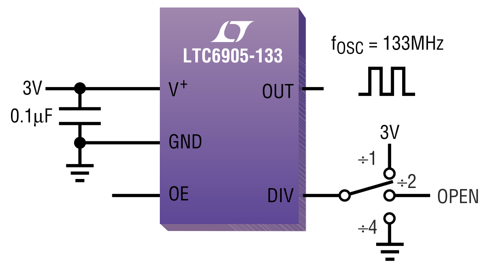


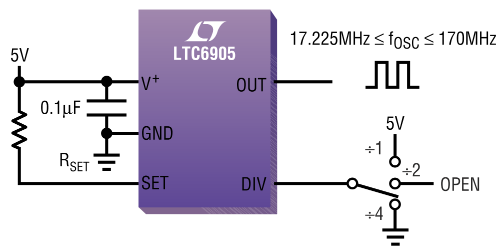
Figure 1. Fixed Frequency Silicon Oscillator

Fixed Frequency Alternative to Can-Type Oscillators

Linear's fixed frequency oscillators are simple, reliable, and robust devices. No trim components are required and these devices exhibit a maximum frequency error of +/-1% at 25°C with stability of 20ppm/°C. Outstanding jitter, rise & fall time, and duty cycle provide an exceptionally "clean" square-wave. Typical start up time is 100µsec and an enable pin is provided for glitch-free control over the output. A divider pin allows division of the master clock frequency (÷1, ÷2, ÷4). Figure 1 shows the LTC®6905-133, which can generate an output frequency of 133MHz, 67MHz or 33.3MHz. Other available frequencies include 100MHz, 96MHz, 80MHz, 50MHz, 48MHz, 40MHz, 25MHz, 24MHz, and 20MHz.

Any Frequency from 1kHz to 170MHz

Linear Technology offers two types of frequency programmable oscillators: resistor programmable and serial programmable. The frequency of a resistor programmable oscillator is set by a single external resistor (R_{SET}) and a pin-strapped divider. These devices can accurately generate a continuously variable frequency



$$f_{OSC} = \left(\frac{168.5\text{MHz} \bullet 10\text{k}\Omega}{R_{SET}} + 1.5\text{MHZ}\right) \bullet \frac{1}{N},\quad N = \begin{cases} 1, & \text{DIV Pin} = V+ \\ 2, & \text{DIV Pin} = \text{Open} \\ 4, & \text{DIV Pin} = \text{GND} \end{cases}$$

$$10\text{k} \le R_{SET} \le 25\text{K}$$

Figure 2. Resistor Set Oscillators

Silicon Oscillators

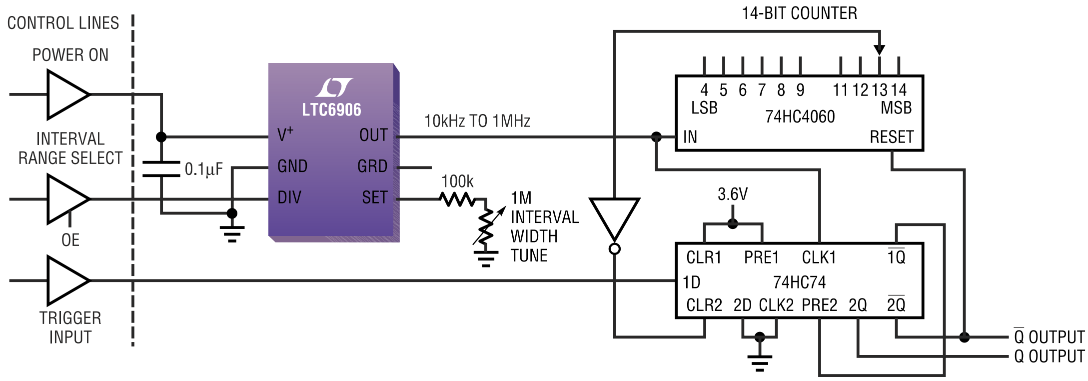


Figure 3. Micropower Tunable TIme Interval Generator

square wave without the use of a crystal, ceramic resonator or external clock reference. R_{SET} is chosen by a simple formula, shown in Figure 2.

The circuit is deceptively simple on the outside. Behind the curtain, however, a proprietary internal feedback loop works to maintain a precise relationship between R_{SET} and the output frequency, with a typical temperature coefficient of only 20ppm/°C and stability over the supply voltage range of 0.5%/V. Using a 0.1% resistor typically provides better than 0.6% accuracy from 0° to 70°C.

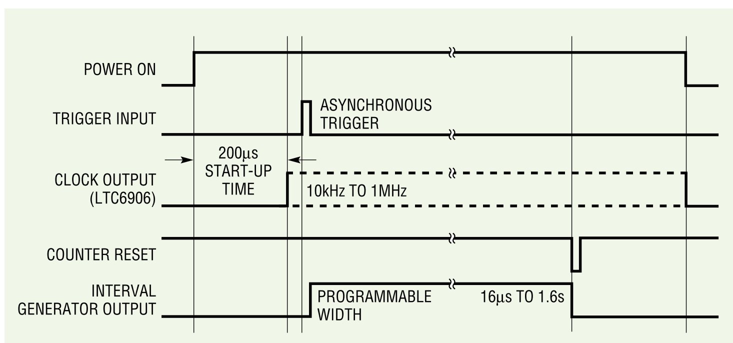


Figure 4. Timing Diagram for Time Interval Generator

Serial programmable oscillators are in many ways similar devices. The LTC6903/4 feature either an SPI or I²C-compatible interface. Frequency can be set "on-the-fly" via an internal 10-bit DAC, with 4 additional bits to set the desired range, resulting in an output span of 1kHz to 68MHz with 0.1% resolution. Programming the frequency is simple, and no external components are required other than a bypass capacitor.

Why Set the Frequency with a Resistor?

Infinite Frequency Resolution: One resistor sets ANY frequency in the oscillators operating range. This provides non-standard value reference clocks, such as those used in switched-capacitor filters. This adjustability also provides capability for adjustments late in the design cycle. Alternatively, this adjustment can be made during production calibration by using R_{SET} as a final trimmer.

Tiny Footprint: With a footprint as small as 9mm² and height of less than 1mm, these circuits are typically 5 to 10 times smaller than alternatives. With such a small solution, the oscillator can be placed right at the point of use, instead of routing fast clock signals over long distances.

Flexibility: Resistor programmable oscillators can be controlled via any method that sources current into the SET pin. This allows for voltage-controlled or current-controlled operation suitable for use in instrumentation (see Applications section).

Applications

If you want to reduce power, you might want to take a second look at your clock. Consider the advantage of replacing your fixed frequency, power-hungry crystal device with a silicon oscillator that

Why Use a Programmable Silicon Oscillator?

Excellent Performance: Silicon oscillators combine stability over temperature (20ppm/°C) and supply voltage (0.5%/V) that far exceeds RC-based oscillators, while offering the tunability that crystals cannot achieve.

Shock, Humidity and EMI Immunity: Silicon oscillators have been tested to over 60,000 Gs without any measurable degradation in performance. Crystals, ceramic resonators and RC oscillators can also be sensitive to EMI as well as humidity.

Fast Start Up: Silicon oscillators power up quickly and predictably, typically within 100µsec. Crystals can take up to 10mS in the MHz range and up to a full second below 100kHz.

Low Power: Power consumption is directly related to the frequency of operation. This is true for crystal, RC and silicon oscillators. However, the power consumption of silicon oscillators at every frequency is 2 to 10 times lower than competing solutions.

Reduced Stocking: Since crystals and ceramic resonators operate at a fixed frequency, a separate part number is required for every frequency needed. Worse, a non-standard frequency could mean a high price and long lead-time. A single part number and some readily available resistors will solve this problem. Using the serially programmable devices, you don't even need the resistors.

can consume significantly less power and can be programmed to operate at different frequencies. As an example, the LTC6906, SOT23 micro-power oscillator consumes only 18µA max at 100kHz.

Viewing these devices for just power reduction, however, ignores their impressive flexibility as the following examples illustrate.

Micropower Tunable Time Interval Generator

An accurate, micropower time interval generator with large dynamic range and excellent stability appears in Figure 3. The circuit consists of a clock, a counter and a dual flip-flop. The LTC6906 silicon oscillator has an extremely low current draw and a fast start up, enabling a standard CMOS gate to awaken the circuit via the power supply pin. The output time interval pulse width is set by the oscillator's frequency and the counter's modulo. As shown, the interval is programmable from 16 µsecs to 1.6 seconds, and additional counters can extend this range. 100ppm stability is achievable over temperature by combining 50ppm resistors with the 50ppm stability of the LTC6906. By powering off the clock

Table 1. Complete Family of SIlicon Oscillators

	Device	Frequency Output	Accuracy (Max 25°C)	Supply Current	Drift	Package	Notes
Fixed Frequency	LTC6905-135	133, 67.7, or 33.3MHz	1%	10mA @133MHz	20ppm/°C	SOT23-5	No trim components required, divide by 1, 2, or 4, output enable-provided 100µs startup time 50ps jitter
	LTC6905-100	100, 50, or 25MHz		8mA @100MHz			
	LTC6905-96	96, 48, or 20MHz		8mA @96MHz			
	LTC6905-80	80, 40, or 20MHz		7mA @80MHz			
Resistor Set	LTC1799	1kHz to 33MHz	1.50%	1mA @3MHz	40ppm/°C	SOT23-5	Wide frequency range
	LTC6900	1kHz to 20MHz	1.50%	500µA @3MHz	40ppm/°C		Low power, 50µsec startup
	LTC6902	5kHz to 20MHz	1.50%	700µA @3MHz	40ppm/°C	MS-10	Spread spectrum with 1, 3 or 4 phase outputs
	LTC6905	17MHz to 170MHz	1.40%	7mA @170MHz	20ppm/°C	SOT23-5	High frequency, 100µsec startup, 50psec jitter, w/ divide by 1, 2 or 4
	LTC6906	10kHz to 1MHz	0.50%	60µA @1MHz	50ppm/°C	SOT23-6	Micropower, no bypass cap
Serial I/F	LTC6903	1kHz to 68MHz (0.1% Resolution)	1.10%	1.7mA @3MHz	10ppm/°C	MS-8	I^2C interface, w/ output enable No trim components required
	LTC6904						SPI interface, w/ output enable No trim components required

Silicon Oscillators

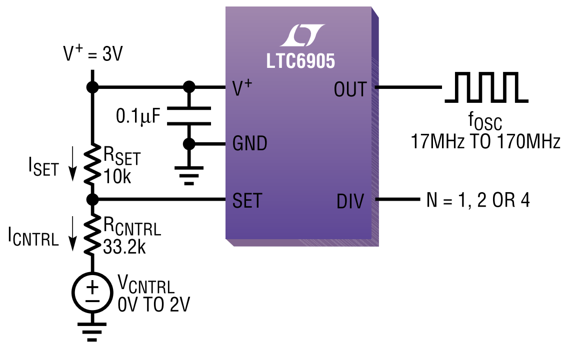


Figure 5. VCO Operation Using the LTC6905

when not needed, the current draw is reduced to the quiescent current of the CMOS flip flop and counter.

WIde Range, Linear VCO

Frequency can be set with Linear Technology's resistor programmable oscillators via any method that sources current into the SET pin. This is particularly useful for the LTC6905 with a wide frequency range of 17MHz to 170MHz. Figure 5 shows the use of a voltage source to control frequency. The R_{SET} resister establishes a constant current into the SET pin, and the current through R_{CNTRL} will subtract from this current to change the frequency. Thus, increasing V_{CNTRL} increases the output frequency. Figure 6 shows the wide frequency range and excellent linearity that can be achieved with this simple technique.

Remote Sensing

Replacing R_{SET} with a resistive-based sensor, such as a thermistor, allows for direct conversion of a sensor output into frequency. In Figure 7, a thermistor is used for a simple temperature-to-frequency generator. By conversion to a digital signal (the CMOS clock output), measurements can be taken remotely and transmitted digitally. An opto-isolator can then be used to electrically isolate the sensor and avoid ground loops. Adding series and parallel resistors for specific thermistors and temperature ranges can improve linearity. Because the resistor programmable oscillators have a small footprint, wide operating range, and low drift, they can be used in this application directly at the point of measurement with minimal design impact.

Microcontroller Applications

Programmable silicon oscillators are also an excellent solution as a microprocessor master clock. For speeds up to 170MHz, these devices provide a stable, flexible clock signal - especially useful if the processor must run at multiple frequencies (such as for sleep and standby). Using either an SPI or I²C-compatible serial interface, the CPU can program its own clock for each mode. Using any of the other Linear Technology oscillators, the frequency can be easily "throttled-back" using the DIV pin. This allows the microcontroller to reduce system power when high-speed operation is not necessary.

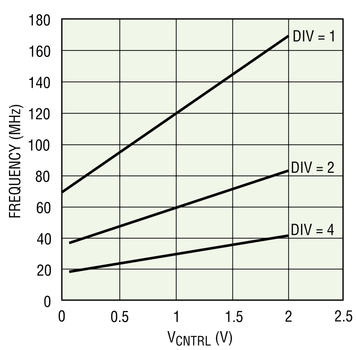


Figure 6. VCO Frequency vs. Voltage at Various Divider Settings

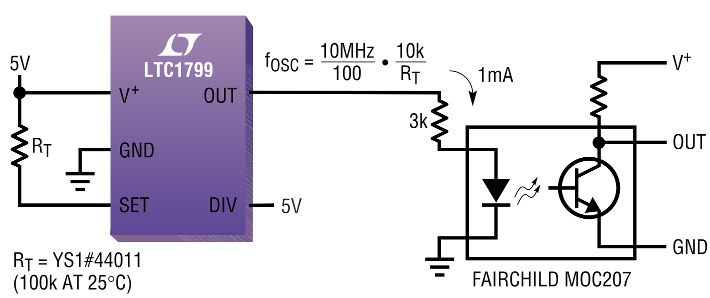


Figure 7. Remote Thermal Sensor Using a Thermistor