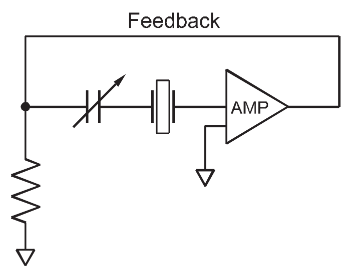
Oscillator Application Notes

A crystal oscillator is a timing device that consists of a crystal and an oscillator circuit, providing an output waveform at a specific frequency. When a crystal is placed into an amplifier circuit (as shown in Figure 1), a small amount of energy is fed back to the crystal, which causes it to vibrate. These vibrations act to stabilize the frequency of the oscillator circuit.

Figure 1. Simplified oscillator circuit using a crystal resonator



Target Frequency

The Target Frequency of an oscillator is the desired output frequency of an oscillator, specified in MHz or kHz (megahertz or kilohertz) @ 25°C. A Frequency Tolerance should be specified along with the Target Frequency.

Overall Frequency Tolerance

Overall Frequency Tolerance is the allowable frequency deviation from the Target Frequency, specified as a maxi mum frequency deviation in ppm (parts per million). The deviation is specified “inclusive” of a set of operating con ditions such as Operating Temperature Range, Supply Voltage, Output Load and Aging.

Operating Temperature Range

The Operating Temperature Range is the specified range to which the device will be exposed during oscillation. All specifications such as Overall Frequency Tolerance, Symmetry and Supply Current will be met within the Operating Temperature Range and is specified as a maximum and a minimum temperature in °C.

Storage Temperature Range

The Storage Temperature Range is the absolute limits of temperature to which the device will be exposed in a non-oscillation state, without being damaged, and is specified as a maximum and a minimum temperature in °C.

Supply Current (Icc)

Supply Current is the amount of current consumption by an oscillator from the power supply, and is usually speci fied as a maximum current in milliamps (mA).

Supply Voltage (Vdd)

Supply Voltage is the DC input voltage range recommended for operation of an oscillator, and is usually specified as a DC voltage with a percentage tolerance. For example: 5.0 Vdc, ±10% is a typical specification. All specifica tions such as Overall Frequency Tolerance, Symmetry and Supply Current will be met within the specified Supply Voltage range.

Symmetry (Duty Cycle)

Symmetry is also commonly referred to as Duty Cycle, and is the measure of output wave uniformity (or symmetry). Symmetry is a measurement of the time that the output waveform is in a logic high state, expressed as a percent age (%) of the complete cycle. A perfectly symmetrical waveform is in a logic high state 50% of the time and in a logic low state 50% of the time, and is expressed as 50/50%. A typical symmetry tolerance is 40/60%. Tight sym metry is considered to be 45/55%. This parameter is measured at a specified voltage threshold or at a percentage of the output waveform. See Figure 2.

Output Voltage Levels (Logic Levels)

The Output Voltage Level High or “Logic 1” and the Output Voltage Level Low or “Logic 0” are voltage thresholds that must be reached by the output waveform of an oscillator. The Output Levels required are dependent upon the type of load the oscillator must drive and the Supply Voltage. HCMOS Output Voltage Levels are sometimes expressed as a percentage of the Supply Voltage. See Figure 2.

Rise / Fall Time

Rise Time is a measure of the transition time from a “Logic 0” to a “Logic 1” level. Fall Time is a measure of the transition time from a “Logic 1” to a “Logic 0” level. Both Rise and Fall Time are typically specified as a maximum transition time in nS (nanoseconds). The transition times are measured at specified voltage thresholds or at speci fied percentages of the output waveform. See Figure 2.

Start Time

Start Time is the time required for the waveform of an oscillator to reach steady state oscillation after power-up, and is usually specified as a maximum time in mS (milliseconds).

Tri-State Output

An oscillator with Tri-State control on pin 1 allows the output to be placed into a high impedance state. This feature is activated by the application of a Control Voltage to pin 1 of the oscillator. VIH and VIL are, respectively, the enable and the disable voltage thresholds of the Tri-State feature.

Output Load

Output Load is the maximum load an oscillator can drive. It is specified in terms of number of gates or type of load circuit. For example: HCMOS, TTL and ECL are the most common load types oscillators must drive. An HCMOS load is usually specified as a capacitive load in pF (picofarads). TTL loads are specified as a number of TTL gates. ECL is specified as a resistive load into a specified voltage. Figures 3 through 5 show oscillator test circuits required for the loads mentioned here. When an oscillator can drive both HCMOS and TTL loads under all speci fied operating conditions, the nomenclature is HCMOS/TTL compatible. The type of load the oscillator must drive is a determining factor for the voltage thresholds used when measuring waveform parameters such as Logic Levels, Duty Cycle and Rise/Fall Time.

VCXO (Voltage Controlled Crystal Oscillator)

A VCXO is an oscillator that allows the user to vary the Output Frequency by varying a Control Voltage applied to pin 1. Figure 5 shows a VCXO and a VCTCXO test circuit.

Control Voltage

Control Voltage is usually specified by a maximum and a minimum voltage that can be applied to pin 1 of a VCXO or a VCTCXO oscillator. Typical Control Voltage ranges are 0.5 to 4.5 Vdc for a 5.0 Vdc Supply Voltage, and 0.3 to 3.0 Vdc for a 3.3 Vdc Supply Voltage.

Center Frequency

The Center Frequency of a VCXO or a VCTCXO is the Output Frequency at the center Control Voltage @ 25°C. It is specified as a Target Frequency with an allowable frequency deviation from the Target Frequency. The Target Frequency is specified in MHz (megahertz) or kHz (kilohertz) and Frequency Tolerance is specified in ±ppm (parts per million). For example: 20 MHz, ±25 ppm @ 25°C is a typical specification of a Center Frequency.

Pullability

Pullability is the change in output frequency with respect to the Center Frequency, resulting from a minimum to a maximum change in control voltage. It is specified as ±ppm (parts per million). For example, a typical pullability specification would be ±100 ppm, which means the Output Frequency should change at least -100 ppm and +100 ppm from the Center Frequency when the Control Voltage is set to it's minimum and maximum levels, respectively.

Linearity

Linearity is the maximum allowable deviation from the best straight-line slope of frequency vs. control voltage, and is specified in a ±% error. Typical linearity specifications are ±20% and ±10%.

TCXO (Temperature Compensated Crystal Oscillator)

A TCXO is a crystal oscillator with a temperature compensated network. A typical Overall Frequency Tolerance that can be achieved by a TCXO is ±0.5 ppm to ±5.0 ppm. A TCXO network often includes a trimmer capacitor that can be used either to compensate for frequency shifts due to aging and/or tune the oscillator to an exact frequency. Many VCXO terms defined, such as Center Frequency and Pullability, also apply to TCXO specifications. However, in TCXO specifications, these terms refer to the frequency tolerance and pullability within the range of a trimmer capacitor instead of a Control Voltage. Since TCXO's have trimmer capacitors that must be accessible, they are not usually hermetically sealed or suited for exposure to the elements.

VCTCXO (Voltage Controlled Temperature Compensated Crystal Oscillator)

A VCTCXO is a VCXO with a temperature compensated network that can achieve Overall Frequency Tolerances similar to TCXO's. A VCTCXO uses a Control Voltage instead of a trimmer capacitor to compensate for frequency shifts due to aging and/or tune the oscillator to an exact frequency. VCTCXO's are hermetically sealed.

Tuning Sensitivity

For a TCXO, Tuning Sensitivity is the slope of frequency change vs. trimmer capacitor change, specified in ppm/pF. For a VCTCXO, Tuning Sensitivity is the slope of frequency change vs. Control Voltage change, specified in ppm/Volt.

Tuning Range

Tuning Range is the range to which the frequency can be adjusted by the trimmer capacitor or Control Voltage, and is usually specified as a minimum range. For example, ±5.0 ppm min. is a typical Tuning Range specification.

Oscillator Waveform and Test Circuits for Various Load Types

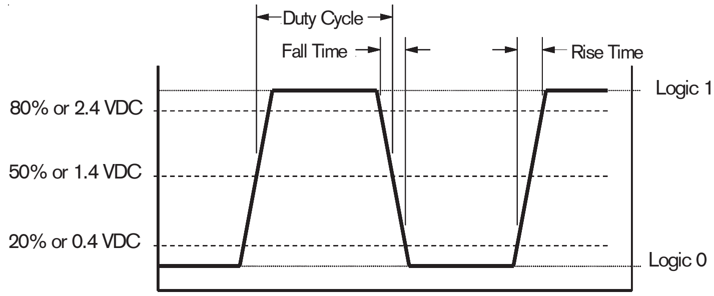


Figure 2. Waveform of HCMOS/TTL compatible oscillators

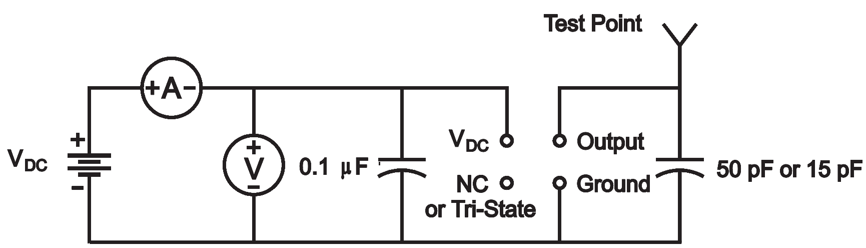


Figure 3. HCMOS Test Circuit

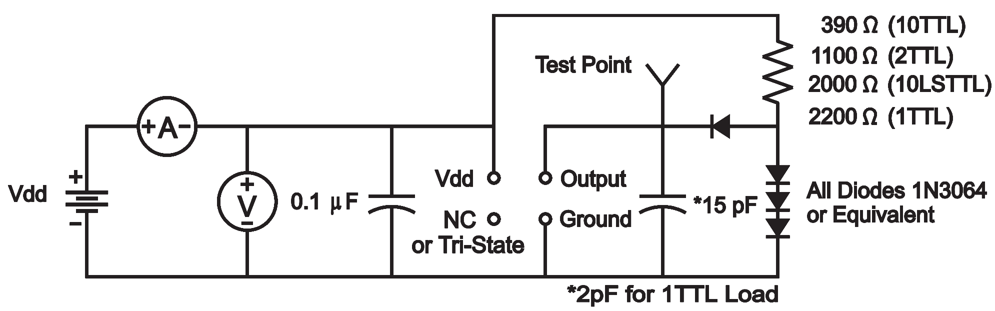


Figure 4. TTL Test Circuit

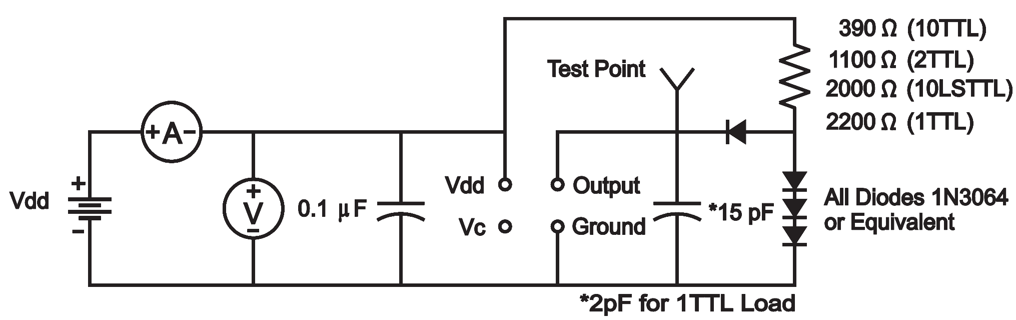


Figure 5. TTL Test Circuit for VCXOs and VCTCXOs. Vc denotes Control Voltage (Pin 1)

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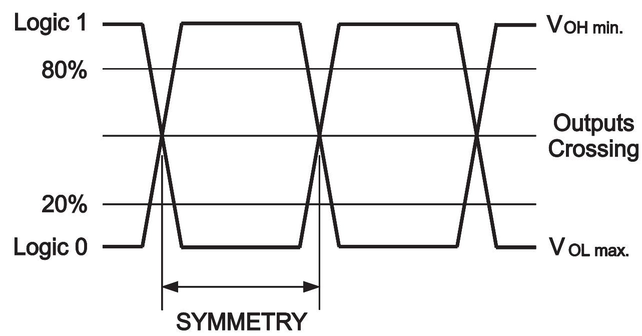

Figure 6. Waveform of PECL & ECL Clock Oscillator Complimentary Output

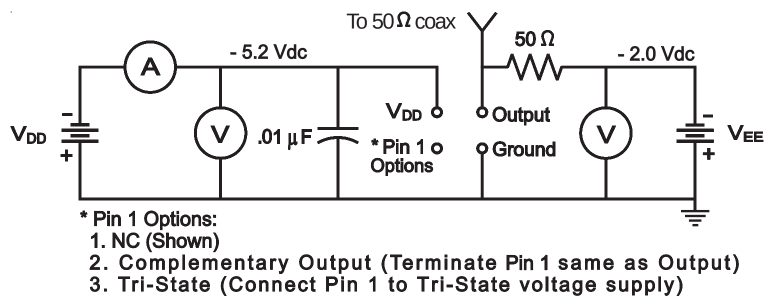

Figure 7. ECL Clock Oscillator Test Circuit

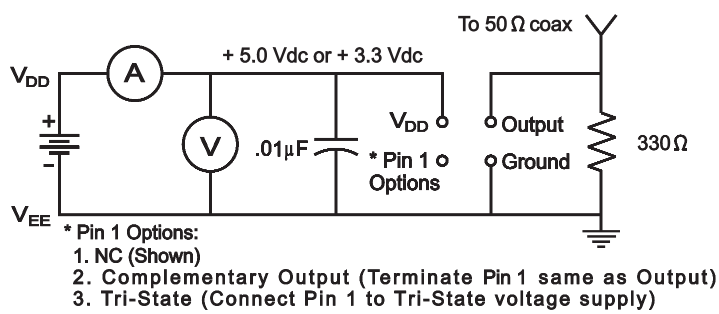

Figure 8. PECL Clock Oscillator Test Circuit

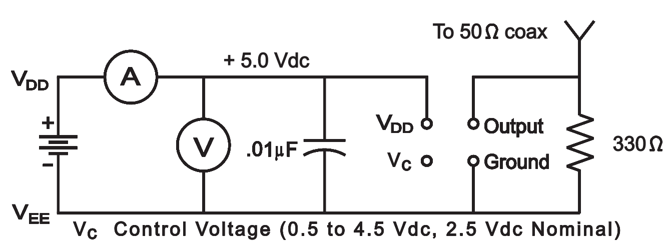

Figure 9. PECL VCXO Test Circuit