# EXAR XR-8038

# Precision Waveform Generator

## GENERAL DESCRIPTION

The XR-8038 is a precision waveform generator IC capable of producing sine, square, triangular, sawtooth and pulse waveforms with a minimum number of external components and adjustments. Its operating frequency can be selected over nine decades of frequency, from 0.001 Hz to 1 MHz by the choice of external R-C components. The frequency of oscillation is highly stable over a wide range of temperature and supply voltage changes. The frequency control, sweep and modulation can be accomplished with an external control voltage, without affecting the quality of the output waveforms. Each of the three basic waveforms, i.e., sinewave, triangle and square wave outputs are available simultaneously, from independent output terminals.

The XR-8038 monolithic waveform generator uses advanced processing technology and Schottky-barrier diodes to enhance its frequency performance. It can be readily interfaced with a monolithic phase-detector circuit, such as the XR-2208, to form stable phase-locked loop circuits.

## FEATURES

Direct Replacement for Intersil 8038
Low Frequency Drift—50 ppm/°C Max.
Simultaneous Sine, Triangle and Square-Wave Outputs
Low Distortion—THD ≃ 1%
High FM and Triangle Linearity
Wide Frequency Range—0.001 Hz to 1 MHz
Variable Duty-Cycle—2% to 98%

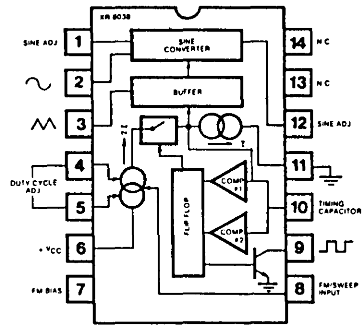
## APPLICATIONS

Precision Waveform Generation Sine, Triangle, Square, Pulse
Sweep and FM Generation
Tone Generation
Instrumentation and Test Equipment Design
Precision PLL Design

## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| Power Supply | 36V |
| Power Dissipation (package limitation) | |
| Ceramic package | 750 mW |
| Derate above +25°C | 6.0 mW/°C |
| Plastic package | 625 mW |
| Derate above +25°C | 5 mW/°C |
| Storage Temperature Range | −65°C to +150°C |

## FUNCTIONAL BLOCK DIAGRAM




## ORDERING INFORMATION

| Part Number | Package | Operating Temperature |
|---|---|---|
| XR-8038M | Ceramic | −55°C to +125°C |
| XR-8038N | Ceramic | 0°C to +70°C |
| XR-8038P | Plastic | 0°C to +70°C |
| XR-8038CN | Ceramic | 0°C to +70°C |
| XR-8038CP | Plastic | 0°C to +70°C |

## SYSTEM DESCRIPTION

The XR-8038 precision waveform generator produces highly stable and sweepable square, triangle and sine waves across nine frequency decades. The device time base employs resistors and a capacitor for frequency and duty cycle determination. The generator contains dual comparators, a flip-flop driving a switch, current sources, a buffer amplifier and a sine wave converter. Three identical frequency waveforms are simultaneously available. Supply voltage can range from 10V to 30V, or ±5V with dual supplies.

Unadjusted sine wave distortion is typically less than 0.7%, with Pin 1 open and 8 kΩ from Pin 12 to Pin 11 ($-V_{EE}$ or ground). Sine wave distortion may be improved by including two 100 kΩ potentiometers between $V_{CC}$ and $V_{EE}$ (or ground), with one wiper connected to Pin 1 and the other connected to Pin 12.

Frequency sweeping or FM is accomplished by applying modulation to Pins 7 and 8 for small deviations, or only to Pin 8 for large shifts. Sweep range typically exceeds 1000:1.

The square wave output is an open collector transistor; output amplitude swing closely approaches the supply voltage. Triangle output amplitude is typically 1/3 of the supply, and sine wave output reaches 0.22 $V_S$.

# XR-8038



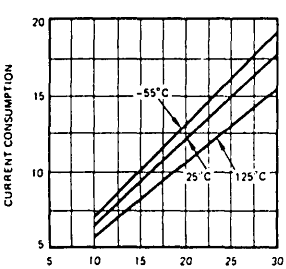
## ELECTRICAL CHARACTERISTICS

**Test Conditions:** $V_S = \pm 5V$ to $\pm 15V$, $T_A = 25°C$, $R_L = 1\ M\Omega$, $R_A = R_B = 10\ k\Omega$, $C_1 = 3300\ pF$, $S_1$ closed, unless otherwise specified. See Test Circuit of Figure 1.

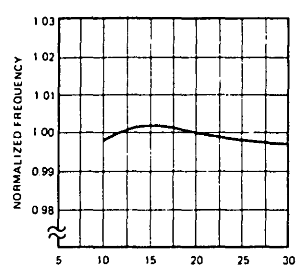
| PARAMETERS | XR-8038M/XR-8038 MIN | XR-8038M/XR-8038 TYP | XR-8038M/XR-8038 MAX | XR-8038C MIN | XR-8038C TYP | XR-8038C MAX | UNITS | CONDITIONS |
|---|---|---|---|---|---|---|---|---|
| **GENERAL CHARACTERISTICS** | | | | | | | | |
| Supply Voltage, $V_S$ | | | | | | | | |
| Single Supply | 10 | | 30 | 10 | | 30 | V | |
| Dual Supplies | ±5 | | ±15 | ±5 | | ±15 | V | |
| Supply Current | | 12 | 15 | | 12 | 20 | mA | $V_S = \pm 10V$. See Note 1. |
| **FREQUENCY CHARACTERISTICS (Measured at Pin 9)** | | | | | | | | |
| Range of Adjustment | | | | | | | | |
| Max. Operating Frequency | | 1 | | | 1 | | MHz | $R_A = R_B = 500\Omega$, $C_1 = 0$, $R_L = 15\ k\Omega$ |
| Lowest Practical Frequency | | 0.001 | | | 0.001 | | Hz | $R_A = R_B = 1\ M\Omega$, $C_1 = 500\ \mu F$ |
| Max. FM Sweep Frequency | | 100 | | | 100 | | kHz | |
| FM Sweep Range | | 1000:1 | | | 1000:1 | | | $S_1$ Open. See Notes 2 and 3. |
| FM Linearity | | 0.1 | | | 0.2 | | % | $S_1$ Open. See Note 3. |
| Range of Timing Resistors | 0.5 | | 1000 | 0.5 | | 1000 | kΩ | Values of $R_A$ and $R_B$ |
| Temperature Stability | | | | | | | | |
| XR-8038M | | 20 | 50 | — | — | — | ppm/°C | |
| XR-8038 | | 50 | 100 | — | — | — | ppm/°C | |
| XR-8038C | — | — | — | | 50 | | ppm/°C | |
| Power Supply Stability | | 0.05 | | | 0.05 | | %/V | See Note 4. |
| **OUTPUT CHARACTERISTICS** | | | | | | | | |
| Square-Wave | | | | | | | | Measured at Pin 9. |
| Amplitude | 0.9 | 0.98 | | 0.9 | 0.98 | | x $V_S$ | $R_L = 100\ k\Omega$ |
| Saturation Voltage | | 0.2 | 0.4 | | 0.2 | 0.5 | V | $I_{sink} = 2\ mA$ |
| Rise Time | | 100 | | | 100 | | nsec | $R_L = 4.7\ k\Omega$ |
| Fall Time | | 40 | | | 40 | | nsec | $R_L = 4.7\ k\Omega$ |
| Duty Cycle Adj. | 2 | | 98 | 2 | | 98 | % | |
| Triangle/Sawtooth/Ramp | | | | | | | | Measured at Pin 3. |
| Amplitude | 0.3 | 0.33 | | 0.3 | 0.33 | | x $V_S$ | $R_L = 100\ k\Omega$ |
| Linearity | | 0.05 | | | 0.1 | | % | |
| Output Impedance | | 200 | | | 200 | | Ω | $I_{out} = 5\ mA$ |
| Sine-Wave Amplitude | 0.2 | 0.22 | | 0.2 | 0.22 | | x $V_S$ | $R_L = 100\ k\Omega$ |
| Distortion | | | | | | | | |
| Unadjusted | | 0.7 | 1.5 | | 0.8 | 3 | % | $R_L = 1\ M\Omega$. See Note 5. |
| Adjusted | | 0.5 | | | 0.5 | | % | $R_L = 1\ M\Omega$ |

**Note 1:** Currents through $R_A$ ad $R_B$ not included.
**Note 2:** $V_S = 20V$, $f = 10\ kHz$, $R_A = R_B = 10k\Omega$.
**Note 3:** Apply sweep voltage at Pin 8. $(2/3\ V_S + 2V) \leq V_{sweep} \leq V_S$
**Note 4:** $10V \leq V_S \leq 30V$ or $\pm 5V \leq V_S \leq \pm 15V$.
**Note 5:** 81 kΩ resistor connected between Pins 11 and 12.

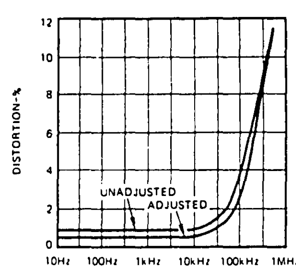
## CHARACTERISTIC CURVES




Power Dissipation vs. Supply Voltage




Frequency Drift vs. Power Supply




Sinewave THD vs. Frequency

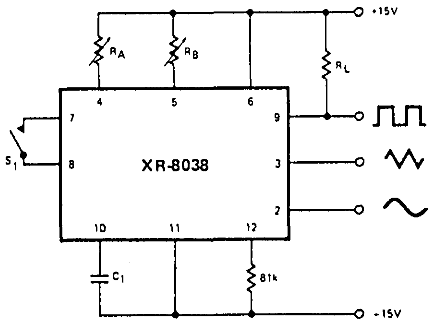



**Figure 1. Generalized Test Circuit**

## WAVEFORM ADJUSTMENT

The *symmetry* of all waveforms can be adjusted with the external timing resistors. Two possible ways to accomplish this are shown in Figure 2. Best results are obtained by keeping the timing resistors $R_A$ and $R_B$ separate (a). $R_A$ controls the rising portion of the triangle and sine-wave and the "Low" state of the square wave.

The magnitude of the triangle waveform is set at 1/3 $V_{CC}$; therefore, the duration of the rising portion of the triangle is:

$$t_1 = \frac{C \times V}{I} = \frac{C \times 1/3 \times V_{CC} \times R_A}{1/5 \times V_{CC}} = \frac{5}{3} R_A \times C$$

The duration of the falling portion of the triangle and the sinewave, and the "Low" state of the square wave is:

$$t_2 = \frac{C \times V}{I} = \frac{C \times 1/3\, V_{CC}}{\frac{2}{5} \times \frac{V_{CC}}{R_B} - \frac{1}{5} \times \frac{V_{CC}}{R_A}} = \frac{5}{3} \times \frac{R_A R_B C}{2R_A - R_B}$$

Thus a 50% duty cycle is achieved when $R_A = R_B$.

If the duty-cycle is to be varied over a small range about 50% only, the connection shown in Figure 2b is slightly more convenient. If no adjustment of the duty cycle is desired, terminals 4 and 5 can be shorted together, as shown in Figure 2c. This connection, however, carries an inherently larger variation of the duty-cycle.

With two separate timing resistors, the *frequency* is given by

$$f = \frac{1}{t_1 + t_2} = \frac{1}{\frac{5}{3} R_A C \left(1 + \frac{R_B}{2R_A - R_B}\right)}$$

or, if $R_A = R_B = R$

$$f = 0.3/RC \text{ (for Figure 2a)}$$

If a single timing resistor is used (Figures 2b and c), the frequency is

$$f = 0.15/RC$$

The frequency of oscillation is independent of supply voltage, even though none of the voltages are regulated inside the integrated circuit. This is due to the fact that both currents *and* thresholds are direct, linear function of the supply voltage and thus their effects cancel.

## DISTORTION ADJUSTMENT

To minimize *sine-wave* distortion the 81 kΩ resistor between pins 11 and 12 is best made a variable one. With this arrangement distortion of less than 1% is achievable. To reduce this even further, two potentiometers can be connected as shown in Figure 3. This configuration allows a reduction of sine-wave distortion close to 0.5%

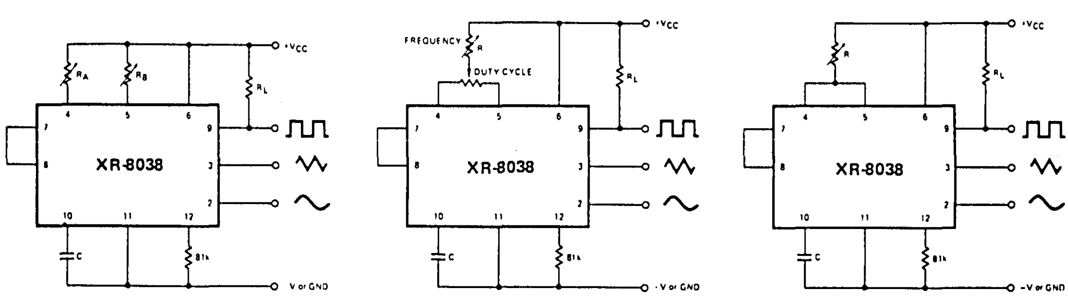



**Figure 2. Possible Connections for the External Timing Resistors.**

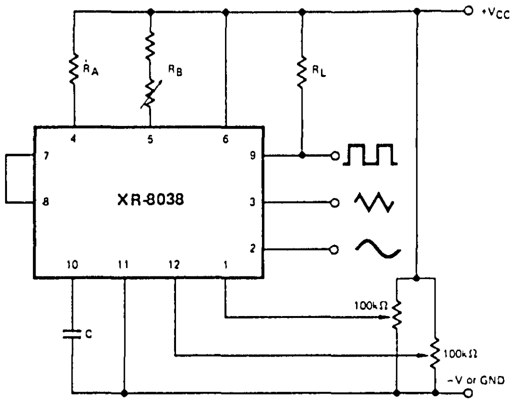



**Figure 3. Connection to Achieve Minimum Sine-Wave Distortion.**

## SELECTING TIMING COMPONENTS

For any given output frequency, there is a wide range of RC combinations that will work. However certain constraints are placed upon the magnitude of the charging current for optimum performance. At the low end, currents of less than 0.1 $\mu$A are undesirable because circuit leakages will contribute significant errors at high temperatures. At higher currents (1 > 5 mA), transistor betas and saturation voltages will contribute increasingly larger errors. Optimum performance will be obtained for charging currents of 1 $\mu$ to 1 mA. If pins 7 and 8 are shorted together the magnitude of the charging current due to $R_A$ can be calculated from:

$$I = \frac{R_1 \times V_{CC}}{(R_1 + R_2)} \times \frac{1}{R_A} = \frac{V_{CC}}{5R_A}$$

A similar calculation holds for $R_B$.

When the duty cycle is greater than 60%, the device may not oscillate every time, unless:

1) the rise times of the V+ is 10x slower than $R_A \cdot C_T$.

2) a 0.1 $\mu$F capacitor is tied from Pin 7 and 8 to ground.

NOTE: This is only needed if the duty cycle is powered up with $R_A >> R_B$.

## SINGLE-SUPPLY AND SPLIT-SUPPLY OPERATION

The waveform generator can be operated either from a single power-supply (10 to 30 Volts) or a dual power-supply (±5 to ±15 Volts). With a single power-supply the average levels of the triangle and sine-wave are at exactly one-half of the supply voltage, while the square-wave alternates between $+V_{CC}$ and ground. A split power supply has the advantage that all waveforms move symmetrically about ground.

The square-wave output is not committed. A load resistor can be connected to a different power-supply, as long as the applied voltage remains within the breakdown capability of the waveform generator (30V). In this way, the square-wave output will be TTL compatible (load resistor connected to +5 Volts) while the waveform generator itself is powered from a higher supply voltage.

## FREQUENCY MODULATION AND SWEEP

The frequency of the waveform generator is a direct function of the DC voltage at terminal 8 (measured from $+V_{CC}$). By altering this voltage, frequency modulation is performed.

For small deviations (e.g., ±10%) the modulating signal can be applied directly to pin 8 by merely providing ac coupling with a capacitor, as shown in Figure 4a. An external resistor between pins 7 and 8 is not necessary, but it can be used to increase input impedance. Without it (i.e. terminals 7 and 8 connected together), the input impedance is 8kΩ); with it, this impedance increases to (R + 8kΩ).

For larger FM deviations or for frequency sweeping, the modulating signal is applied between the positive supply voltage and pin 8 (Figure 4b). In this way the entire bias for the current sources is created by the modulating signal and a very large (e.g., 1000:1) sweep range is obtained (f = 0 at $V_{Sweep}$ = 0). Care must be taken, however, to regulate the supply voltage; in this configuration the charge current is no longer a function of the supply voltage (yet the trigger thresholds still are) and thus the frequency becomes dependent on the supply voltage. The potential on Pin 8 may be swept from $V_{CC}$ to 2/3 $V_{CC}$ −2V.



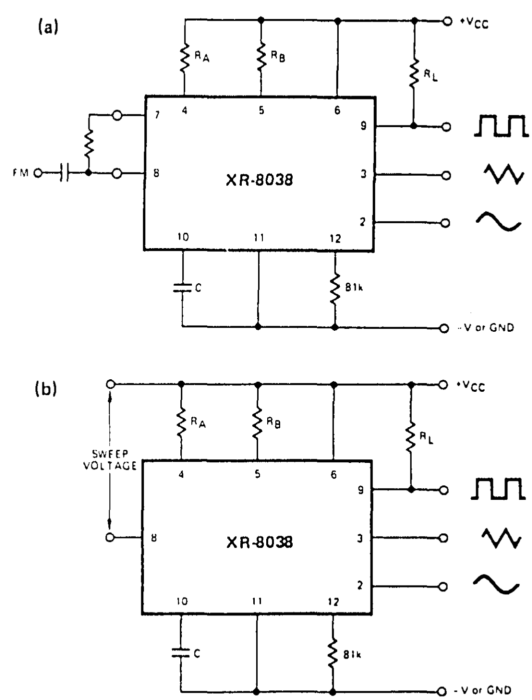



**Figure 4. Connections for Frequency Modulation (a) and Sweep (b).**