EXAR

XR-8038

Precision Waveform Generator

T-50-09

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 eight decades of frequency, from 0.001Hz to 200KHz 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. Both full frequency sweeping as well as smaller frequency variations (FM) can be accomplished with an external control voltage. 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.

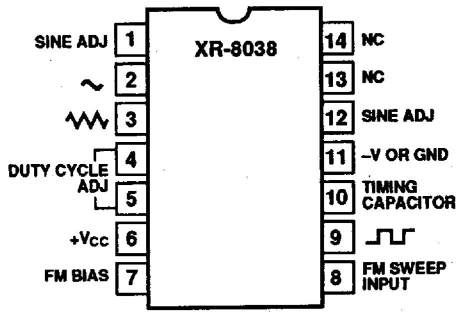
FEATURES

Pin for pin replacement for Intersil 8038
With Improved Sweep Range, Frequency Drift (50 ppm/°C Typ.), and Max. Operating Frequency
Simultaneous Sine, Triangle and Square-Wave Outputs
Low Sine Wave Distortion — THD ≃ 1%
High FM and Triangle Linearity
Wide Frequency Range — 0.001Hz to 200KHz
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

PIN ASSIGNMENT



ABSOLUTE MAXIMUM RATINGS

Power Supply	36V
Power Dissipation (package limitation)	
Ceramic package	750mW
Derate above +25°C	6.0mW/°C
Plastic package	625mW
Derate above +25°C	5mW/°C
SO-14	390mW
Derate above +25°C	3mW/°C
Storage Temperature Range	–66°C to +150°C

Note: Combinations of V_{CC}, V_{EE} and timing resistors may exceed the above value. Caution is recommended.

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
XR-8038MD	Japanese SOIC	0°C to +70°C

T-5D-09

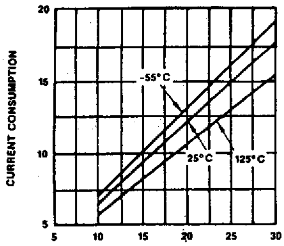
ELECTRICAL CHARACTERISTICS

Test Conditions: $V_S = \pm5V$ to $\pm15V$, $T_A = 25°C$, $R_L = 1M\Omega$, $R_A = R_B = 10k\Omega$, $C_1 = 3300pF$, S_1 closed, unless otherwise specified. See Test Circuit of Figure 1.

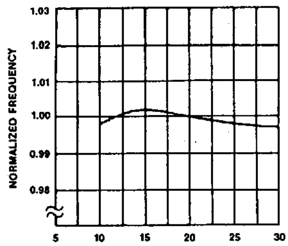
PARAMETERS	XR-8038M/XR8038 MIN	XR-8038M/XR8038 TYP	XR-8038M/XR8038 MAX	XR8038C MIN	XR8038C TYP	XR8038C MAX	UNITS	CONDITIONS
GENERAL CHARACTERISTICS								
Supply Voltage, V_S								
Single Supply	10		30	10		30	V	
Dual Supplies	±5		±15	±5		±15	V	
Supply Current		12	15		12	20	mA	$V_S = \pm10V$. See Note 1.
FREQUENCY CHARACTERISTICS (Measured at Pin 9)								
Range of Adjustment								
Max. Operating Frequency	200			200			KHz	$R_A = R_B, = 1.5k\Omega$, $C_1 = 680pF$ $R_L = 10k\Omega$
Lowest Practical Frequency		0.001			0.001		Hz	$R_A = R_B = 1M\Omega$, $C_1 = 500\ \mu F$ (Low Leakage Capacitor)
Max. Sweep Frequency of								
FM Input		100			100		kHz	
FM Sweep Range		1000:1			1000:1			S_1 Open. See Notes 2 and 3.
FM Linearity 10:1 Ratio		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		50	100	—	—	—	ppm/°C	$T_T = 0°C$ to $70°C$ *See note 8
XR-8038AM		125	150				PPm/°C	$T_T = -55°C$ to $+125°C$ *See note 8
XR-8038		50	100	—	—	—	ppm/°C	
XR-8038C	—	—	—		50		ppm/°C	$T_T = 0°C$ to $70°C$ *See note 8
Power Supply Stability		0.05			0.05		%/V	See Note 4.
OUTPUT CHARACTERISTICS								
Square-Wave								Measured at Pin 9.
Amplitude (Peak-to-Peak)	0.9	0.98		0.9	0.98		X V_{SPLY}	$R_L = 100k\Omega$
Saturation Voltage		0.2	0.4		0.2	0.5	V	$I_{sink} = 2mA$
Rise Time		100			100		nsec	$R_L = 4.7k\Omega$
Fall Time		40			40		nsec	$R_L = 4.7k\Omega$
Duty Cycle Adj.	2		98	2		98	%	
Triangle/Sawtooth/Ramp								Measured at Pin 3.
Amplitude (Peak-to-Peak)	0.3	0.33		0.3	0.33		X V_{SPLY}	$R_L = 100k\Omega$
Linearity		0.05			0.1		%	
Output Impedance		200			200		Ω	$I_{OUT} = 5mA$
Sine-Wave Amplitude (Peak-to-Peak)	0.2	0.22		0.2	0.22		X V_{SPLY}	$R_L = 100k\Omega$
Distortion								
Unadjusted		0.7	1.5		0.8	3	%	$R_L = 1M\Omega$ See Note 5, 6 and 7.
Adjusted		0.5			0.5		%	$R_L = 1M\Omega$

Note 1: Currents through R_A and R_B not included.
Note 2: $V_{SUPPLY} = 20V$.
Note 3: Apply sweep voltage at Pin 8.
$V_{CC} - (1/3\ V_{SUPPLY} - 2) \le V_{PIN\ 8} \le V_{CC}$
V_{SUPPLY} = Total Supply Voltage across the IC
Note 4: $10V \le V_s < 30V$ or $\pm5V \le V_s \le 15V$.
Note 5: 82kΩ resistor connected between Pins 11 and 12.
Note 6: Triangle duty cycle set at 50%, use R_A and R_B.
Note 7: As R_L is decreased distortion will increase, R_L min ≈ 50kΩ.
Note 8: Guaranteed but not tested.

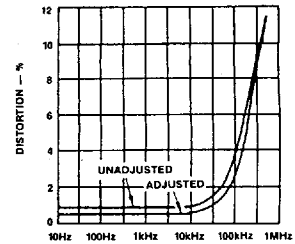
CHARACTERISTIC CURVES



Supply Voltage Power Dissipation vs. Supply Voltage



Supply Voltage Frequency Drift vs. Power Supply



Sinewave THD vs. Frequency

SYSTEM DESCRIPTION

The XR-8038 precision waveform generator produces highly stable and sweepable square, triangle, and sine waves across eight 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, buffers, and a sine wave converter. Three identical frequency waveforms are simultaneously available. Supply voltage can range from 10V to 30V, or ±5V to ±15V with dual supplies.

Unadjusted sine wave distortion is typically less than 0.7%, with Pin 1 open and 82kΩ from Pin 12 to Pin 11 (–V or ground). Sine wave distortion may be improved by including two 100kΩ potentiometers between V_{CC} and –V (or ground), with one wiper connected to Pin 1 and the other connected to Pin 12.

Small frequency deviation (FM) is accomplished by applying modulation voltage to Pins 7 and 8; large frequency deviation (sweeping) is accomplished by applying voltage to Pin 8 only Sweep range is typically 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 of the supply voltage.

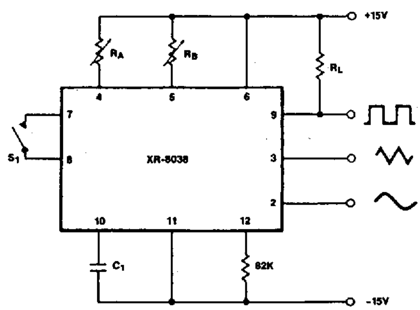


Figure 1. Generalized Test Circuit

PRINCIPLES OF OPERATION

This circuit operates through the charging and discharging of external capacitor C by the currents I_A and $2I_B$. See Figure 3. When switch S is open, current I_A charges capacitor C from V_{CC} – 2/3 V_{SUPPLY} to V_{CC} – 1/3 V_{SUPPLY} (V_{SUPPLY} being the total supply voltage across the chip), at which point comparator #1 switches, causing the flip-flop to change state. As a result of the flip-flop changing state, switch S closes, causing capacitor C to be discharged by the current $2I_B$ – I_A since both current sources are now connected to the capacitor. Capacitor C is discharged from V_{CC} – 1/3 V_{SUPPLY} to V_{CC} – 2/3 V_{SUPPLY}, at which point comparator #2 switches, causing the flip-flop to again change state. Switch S opens, and the cycle begins again with the charging of capacitor C. The charging and discharging of capacitor C creates a triangle wave voltage across the capacitor, which is connected to pin 10. This pin 10 signal is buffered, and the result is the triangle wave output appearing at pin 3. This buffered triangle wave is passed through a sine-converter network, thus creating the sine wave output at pin 2. The square wave output at pin 9 is simply the buffered output of the flip-flop, which changes its output state as a result of the charge and discharge of capacitor C.

Producing a 50% duty cycle square wave output, a symmetrical triangle (as opposed to sawtooth) wave output, and a symmetrically-shaped sine wave output, require that current I_A be chosen equal to current I_B. When I_A is set equal to I_B, the current I_A charging the capacitor is equal to the net current $2I_B - I_A = I_A$ which alternately discharges the capacitor. As a result of this, the waveform appearing at pin 10 is a symmetrical triangle wave, as is the buffered triangle wave output at pin 3. This symmetrical triangle wave output at pin 3 produces a symmetrically-shaped sine wave output at pin 2. Also, the symmetrical triangle wave at pin 10 causes the flip-flop to produce a 50% duty cycle square wave output at pin 9. Sawtooth wave and asymmetrically-shaped sine and square wave outputs can be produced by setting up currents I_A and I_B to be unequal.

In order to understand how magnitudes for currents I_A and I_B are determined, refer to Figure 4. For typical operation of the 8038, Pin 7, the output of the internal voltage divider, is connected to Pin 8. As a result, a voltage of

$$V_{CC} - \frac{R_2 V_{SUPPLY}}{R_1 + R_2} = V_{CC} - \frac{V_{SUPPLY}}{5}$$

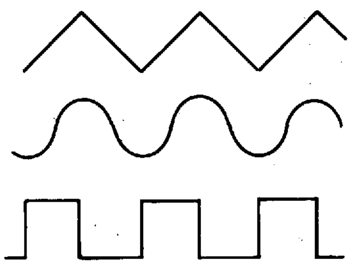
is present at the ends of both timing resistors R_A and R_B (the ends of R_A and R not connected to the positive supply). Consequently,

$$I_A = \frac{V_{CC} - (V_{CC} - \frac{V_{SUPPLY}}{5})}{R_A}$$

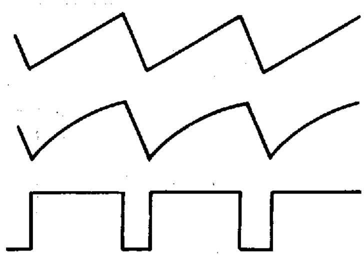
$$I_A = \frac{V_{SUPPLY}}{5R_A}$$

$$I_B = \frac{V_{SUPPLY}}{5R_AB}$$

2



(a) Symmetrical Waveforms



(b) Asymmetrical Waveforms

Figure 2. Phase Relationship of the Triangle, Sine Wave, and Square Wave Outputs

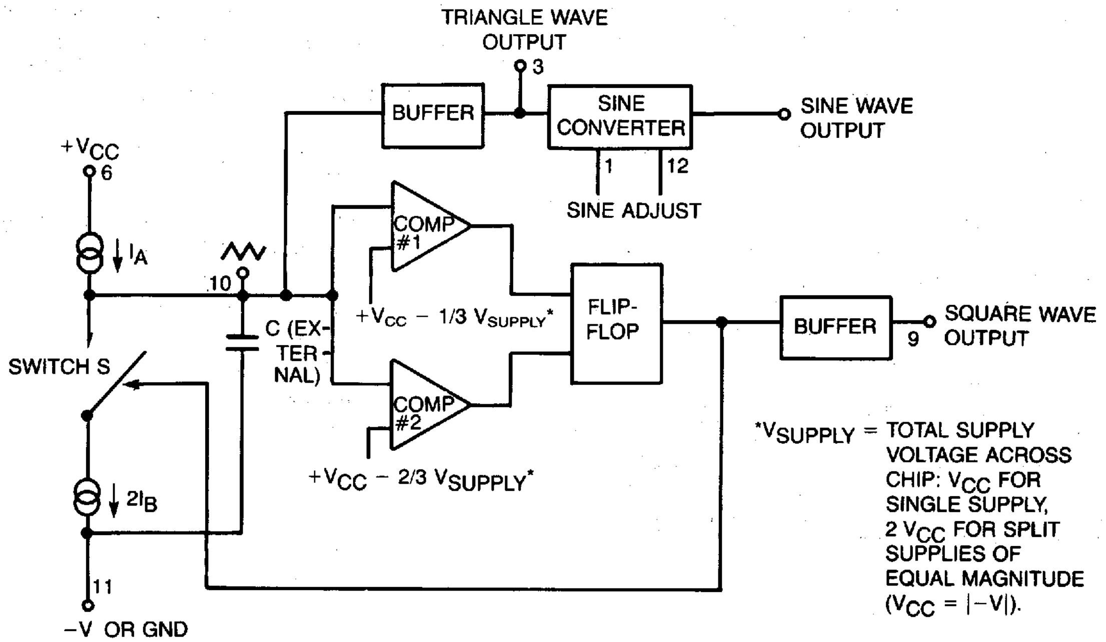


Figure 3. Functional Block Diagram

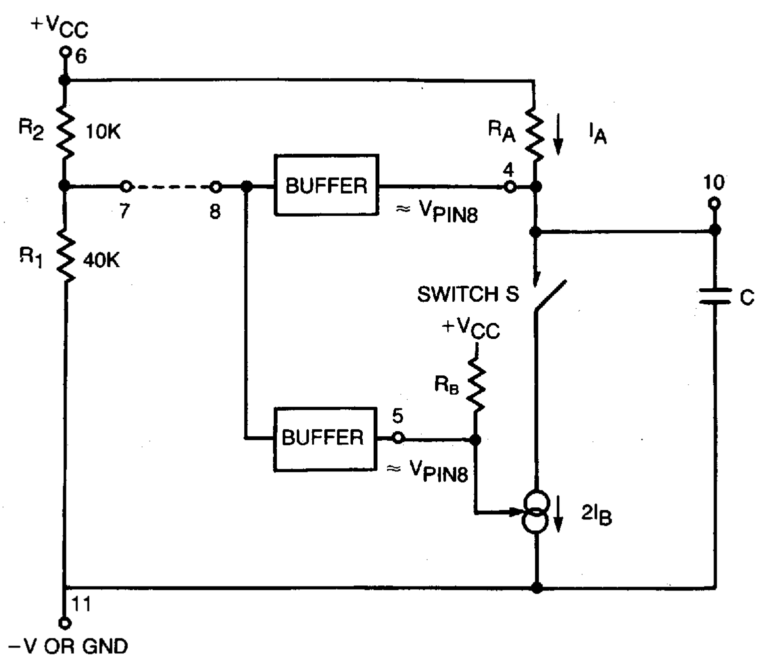


Figure 4. Detailed View of Current Sources I_A and $2I_B$

For the case of SINGLE-SUPPLY operation, these equations can be simplified to

$$I_A = \frac{V_{CC}}{5R_A} \text{ and } I_B = \frac{V_{CC}}{5R_B}.$$

For the case of SPLIT-SUPPLY operation, where the negative and positive supplies are equal in magnitude, the equations for I_A and I_B can be simplified to

$$I_A = \frac{2V_{CC}}{5R_A} \text{ and } I_B = \frac{2V_{CC}}{5R_B}.$$

Waveform Adjustment

The equations pertinent to waveform adjustment are derived here assuming single-supply operation (and the connection of pin 7 to pin 8). However, these same equations for t_1, t_2, and f apply to split-supply operation also, regardless of whether the magnitudes of the positive and negative supplies are equal.

The symmetry of all waveforms can be adjusted with the external timing resistors. Two possible ways to accomplish this are shown in Figures 5a and 5b. Best results are obtained by keeping the timing resistors R_A and R_B separate (5a). R_A controls the rising portion of the triangle and sine waves and the "high" state of the square wave.

Referring to Figure 3, it is apparent that the pin 10 triangle wave will have a minimum amplitude of 1/3 V_{CC} and a maximum amplitude of 2/3 V_{CC}; therefore, the duration of the rising portion of the triangle wave is

$$t_1 = \frac{C \times |\Delta V|}{I_A} = \frac{C \times |2/3\ V_{CC} - 1/3\ V_{CC}|}{\frac{V_{CC}}{5R_A}} = \frac{5}{3} R_A C.$$

The duration of the falling portion of the triangle and sine wave and the "low" state of the square wave is

$$t_1 = \frac{C \times |\Delta V|}{2I_B - I_A} = \frac{C \times |1/3\ V_{CC} - 2/3\ V_{CC}|}{\frac{2V_{CC}}{5R_B} - \frac{V_{CC}}{5R_A}} = \frac{5}{3} \times \frac{R_A R_B C}{2R_A - R_B}.$$

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

It the duty cycle is to be varied over a small range, centered around a duty cycle of 50%, the connection shown in Figure 5b is slightly more convenient. It no adjustment of the duty cycle is desired, pins 4 and 5 can be shorted together, as shown in Figure 5c. This connection, however, carries an inherently larger variation of the duty cycle as frequency is varied.

With two separate timing resistors the frequency is given by

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

or, if $R_A = R_B = R$

f = 0.3/RC (for Figure 5a)

If a single timing resistor is used (Figure 5b and c), the frequency is

f = 0.15/RC.

The frequency accuracy of the 8038 is typically within ±8.5% of the frequency calculated using the above formula f = 0.3/RC (under the test conditions shown at the top of the electrical characteristics section and V_{SUPPLY} = 20V) For tighter frequency accuracies, Pin 8 can be disconnected from Pin 7 and set at $V_{PIN8} = V_{CC} - \frac{V_{SUPPLY}}{5}$. Using this approach, the frequency accuracy of the part is typically within ±4% of the calculated frequency (tested at $V_{CC} = V_{SUPPLY}$ = 20V, V_{PIN8} = 16V).

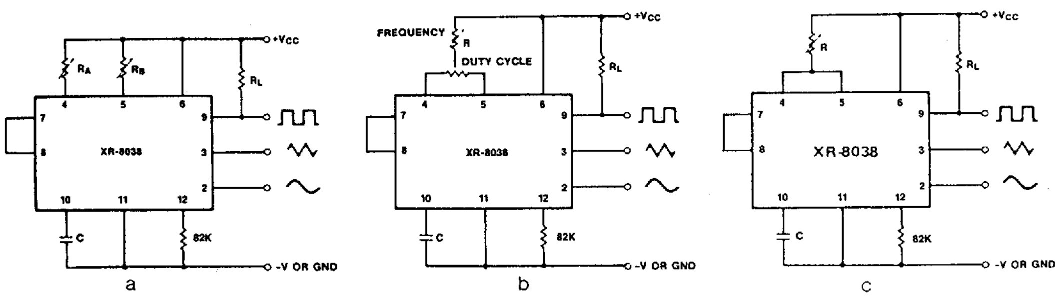


Figure 5. Possible Connections for the External Timing Resistors

Timing Component Constraints

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 0.1μA are undesirable because circuit leakages will contribute significant errors at high temperatures. At higher currents (I > 5mA), transistor betas and saturation voltages will contribute increasingly large errors. Optimum performance will be obtained for charging currents of 1μA to 1mA. To determine the magnitudes of the charging currents I_A and I_B, see the Principles of Operation section.

When the duty cycle is chosen to be greater than 60% or less than 40%, the device may not oscillate every time unless the rise time of the positive supply is ten times slower than the time constant R_A C, for the 60% duty cycle case, or ten times slower than the time constant R_B C, for the 40% duty cycle case. If the rise time of the positive supply is faster than what is required, oscillation can be guaranteed by tying a 0.1μF capacitor from Pins 7 and 8 to ground.

Distortion Adjustment

To minimize sine-wave distortion the 82kΩ 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 6. This configuration allows a reduction of sine-wave distortion close to 0.5%.

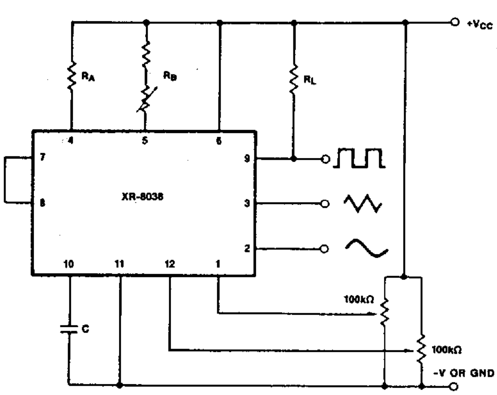


Figure 6. Connection to Achieve Minimum Sine-Wave Distortion

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 (36V). 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 an inverse function of the DC voltage at pin 8. In other words, the frequency increases as the pin 8 voltage is swept from its upper limit of V_{CC} (and slightly higher) to its lower limit of approximately $V_{CC} - (1/3\ V_{SUPPLY} - 2)$.

For small deviations (e.g., ±10%), the modulating signal can be applied to pin 8 through a capacitor while pin 8 is connected to pin 7 (or while pin 8 and pin 7 are connected together through a resistor). This mode of operation (shown in Figure 7a) makes use of the DC bias provided by pin 7 and thus eliminates the need for the modulating signal to have a particular DC level. The external resistor between pins 7 and 8 can be used to increase input impedance. Without this resistor (i.e., pins 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, Pin 7 is not used. Instead, the entire bias for the 8038 current sources is created by the modulating signal at Pin 8. The circuit of Figure 7b, which shows this mode of operation, will allow a sweep range of typically 1000:1, the frequency approaching 0Hz when the voltage at Pin 8 is equal to V_{CC} and the frequency reaching its maximum at the lower Pin 8 voltage limit of $V_{CC} - (1/3\ V_{SUPPLY} - 2)$. Waveform symmetry variations which occur when the frequency is swept can be reduced by adding a large fixed resistor (e.g., 10M) or potentiometer from Pin 5 to Pin 11 (GND or –V). Even with this resistor added, there will still be some symmetry variation at lower frequencies (e.g., 200Hz and lower).

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Care must be taken to regulate the supply voltage, as frequency becomes dependent on the supply voltage in this configuration. The frequency of oscillation of this circuit is given by

$$f = \frac{1}{t_1 + t_2}$$

where $t_1 = \dfrac{R_A C\, V_{SUPPLY}}{3(V_{CC} - V_{PIN8})}$,

and $t_2 = \dfrac{R_A R_B C\, V_{SUPPLY}}{3(V_{CC} - V_{PIN8})(2R_A - R_B)}$;

or, if $R_A = R_B = R$

$t_1 = \dfrac{RC\, V_{SUPPLY}}{3(V_{CC} - V_{PIN8})}$

and $t_2 = \dfrac{RC\, V_{SUPPLY}}{3(V_{CC} - V_{PIN8})}$,

V_{SUPPLY} being the total supply voltage across the chip (e.g., V_{SUPPLY} = 20V for ±10V split supplies).

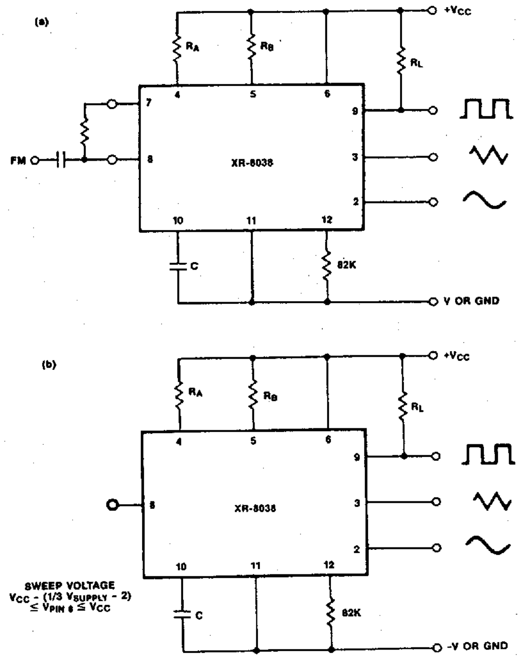

Figure 7. Connections for Frequency Modulation (a) and Sweep (b)