Precision Waveform Generator/Voltage Controlled Oscillator

The ICL8038 waveform generator is a monolithic integrated circuit capable of producing high accuracy sine, square, triangular, sawtooth and pulse waveforms with a minimum of external components. The frequency (or repetition rate) can be selected externally from 0.001Hz to more than 300kHz using either resistors or capacitors, and frequency modulation and sweeping can be accomplished with an external voltage. The ICL8038 is fabricated with advanced monolithic technology, using Schottky barrier diodes and thin film resistors, and the output is stable over a wide range of temperature and supply variations. These devices may be interfaced with phase locked loop circuitry to reduce temperature drift to less than 250ppm/^{o}C.

Features

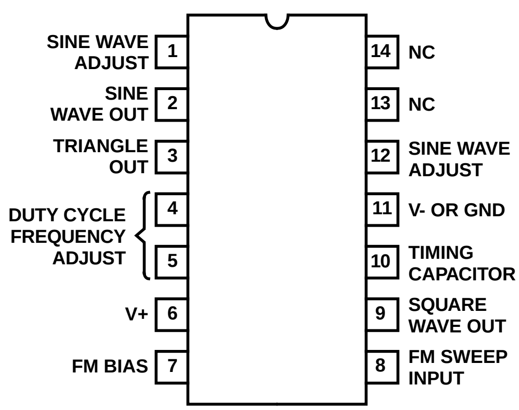
- Low Frequency Drift with Temperature. . . . . . .250ppm/^{o}C
- Low Distortion. . . . . 1% (Sine Wave Output)
- High Linearity . . . . .0.1% (Triangle Wave Output)
- Wide Frequency Range . . . . 0.001Hz to 300kHz
- Variable Duty Cycle . . . . 2% to 98%
- High Level Outputs. . . . . .TTL to 28V
- Simultaneous Sine, Square, and Triangle Wave Outputs
- Easy to Use - Just a Handful of External Components Required

Ordering Information

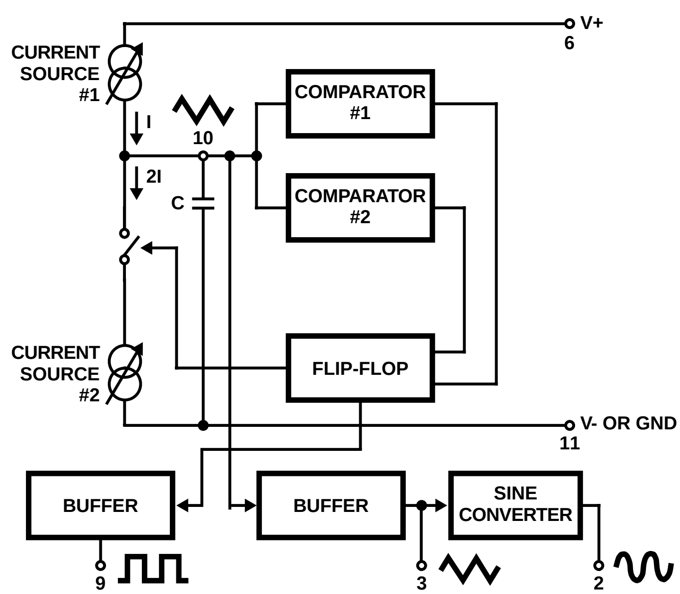
PART NUMBER	STABILITY	TEMP. RANGE (^{o}C)	PACKAGE	PKG. NO.
ICL8038CCPD	250ppm/^{o}C (Typ)	0 to 70	14 Ld PDIP	E14.3
ICL8038CCJD	250ppm/^{o}C (Typ)	0 to 70	14 Ld CERDIP	F14.3
ICL8038BCJD	180ppm/^{o}C (Typ)	0 to 70	14 Ld CERDIP	F14.3
ICL8038ACJD	120ppm/^{o}C (Typ)	0 to 70	14 Ld CERDIP	F14.3

Pinout

ICL8038
(PDIP, CERDIP)
TOP VIEW



Functional Diagram



Absolute Maximum Ratings

Supply Voltage (V- to V+). 36V
Input Voltage (Any Pin) . . . . V- to V+
Input Current (Pins 4 and 5). 25mA
Output Sink Current (Pins 3 and 9) 25mA

Operating Conditions

Temperature Range
ICL8038AC, ICL8038BC, ICL8038CC . . . . 0^oC to 70^oC

Thermal Information

Thermal Resistance (Typical, Note 1)	θ_{JA} ($^oC/W$)	θ_{JC} ($^oC/W$)
CERDIP Package.	75	20
PDIP Package	115	N/A

Maximum Junction Temperature (Ceramic Package) . . . . .175^oC
Maximum Junction Temperature (Plastic Package) . . . . .150^oC
Maximum Storage Temperature Range . . . . -65^oC to 150^oC
Maximum Lead Temperature (Soldering 10s) . . . . 300^oC

Die Characteristics

Back Side Potential . . . . V-

CAUTION: Stresses above those listed in “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

1. θ_{JA} is measured with the component mounted on an evaluation PC board in free air.

Electrical Specifications

V_{SUPPLY} = ±10V or +20V, $T_A = 25^oC$, $R_L = 10k\Omega$, Test Circuit Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS	ICL8038CC			ICL8038BC			ICL8038AC			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage Operating Range	V_{SUPPLY} V+	Single Supply	+10	-	+30	+10	-	+30	+10	-	+30	V
	V+, V-	Dual Supplies	±5	-	±15	±5	-	±15	±5	-	±15	V
Supply Current	I_{SUPPLY}	V_{SUPPLY} = ±10V (Note 2)		12	20	-	12	20	-	12	20	mA
FREQUENCY CHARACTERISTICS (All Waveforms)												
Max. Frequency of Oscillation	f_{MAX}		100	-	-	100	-	-	100	-	-	kHz
Sweep Frequency of FM Input	f_{SWEEP}		-	10	-	-	10	-	-	10	-	kHz
Sweep FM Range		(Note 3)	-	35:1	-	-	35:1	-	-	35:1	-	
FM Linearity		10:1 Ratio	-	0.5	-	-	0.2	-	-	0.2	-	%
Frequency Drift with Temperature (Note 5)	$\Delta f/\Delta T$	0^oC to 70^oC	-	250	-	-	180	-	-	120		$ppm/^oC$
Frequency Drift with Supply Voltage	$\Delta f/\Delta V$	Over Supply Voltage Range	-	0.05	-	-	0.05		-	0.05	-	%/V
OUTPUT CHARACTERISTICS												
Square Wave												
Leakage Current	I_{OLK}	V_9 = 30V	-	-	1	-	-	1	-	-	1	μA
Saturation Voltage	V_{SAT}	I_{SINK} = 2mA	-	0.2	0.5	-	0.2	0.4	-	0.2	0.4	V
Rise Time	t_R	$R_L = 4.7k\Omega$	-	180	-	-	180	-	-	180	-	ns
Fall Time	t_F	$R_L = 4.7k\Omega$	-	40	-	-	40	-	-	40	-	ns
Typical Duty Cycle Adjust (Note 6)	ΔD		2		98	2	-	98	2	-	98	%
Triangle/Sawtooth/Ramp												
Amplitude	$V_{TRIANGLE}$	$R_{TRI} = 100k\Omega$	0.30	0.33	-	0.30	0.33	-	0.30	0.33	-	- xV_{SUPPLY}
Linearity			-	0.1	-	-	0.05	-	-	0.05	-	%
Output Impedance	Z_{OUT}	I_{OUT} = 5mA	-	200	-	-	200	-	-	200	-	Ω

Electrical Specifications

V_{SUPPLY} = ±10V or +20V, T_A = 25°C, R_L = 10kΩ, Test Circuit Unless Otherwise Specified **(Continued)**

PARAMETER	SYMBOL	TEST CONDITIONS	ICL8038CC			ICL8038BC			ICL8038AC			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Sine Wave Amplitude	V_{SINE}	R_{SINE} = 100kΩ	0.2	0.22	-	0.2	0.22	-	0.2	0.22	-	xV_{SUPPLY}
THD	THD	R_S = 1MΩ (Note 4)	-	2.0	5	-	1.5	3	-	1.0	1.5	%
THD Adjusted	THD	Use Figure 4	-	1.5	-	-	1.0	-	-	0.8	-	%

NOTES:

2. R_A and R_B currents not included.
3. V_{SUPPLY} = 20V; R_A and R_B = 10kΩ, f ≅ 10kHz nominal; can be extended 1000 to 1. See Figures 5A and 5B.
4. 82kΩ connected between pins 11 and 12, Triangle Duty Cycle set at 50%. (Use R_A and R_B.)
5. Figure 1, pins 7 and 8 connected, V_{SUPPLY} = ±10V. See Typical Curves for T.C. vs V_{SUPPLY}.
6. Not tested, typical value for design purposes only.

Test Conditions

PARAMETER	R_A	R_B	R_L	C	SW_1	MEASURE
Supply Current	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Current Into Pin 6
Sweep FM Range (Note 7)	10kΩ	10kΩ	10kΩ	3.3nF	Open	Frequency at Pin 9
Frequency Drift with Temperature	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Frequency at Pin 3
Frequency Drift with Supply Voltage (Note 8)	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Frequency at Pin 9
Output Amplitude (Note 10)						
Sine	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Pk-Pk Output at Pin 2
Triangle	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Pk-Pk Output at Pin 3
Leakage Current (Off) (Note 9)	10kΩ	10kΩ		3.3nF	Closed	Current into Pin 9
Saturation Voltage (On) (Note 9)	10kΩ	10kΩ		3.3nF	Closed	Output (Low) at Pin 9
Rise and Fall Times (Note 11)	10kΩ	10kΩ	4.7kΩ	3.3nF	Closed	Waveform at Pin 9
Duty Cycle Adjust (Note 11)						
Max	50kΩ	~1.6kΩ	10kΩ	3.3nF	Closed	Waveform at Pin 9
Min	~25kΩ	50kΩ	10kΩ	3.3nF	Closed	Waveform at Pin 9
Triangle Waveform Linearity	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Waveform at Pin 3
Total Harmonic Distortion	10kΩ	10kΩ	10kΩ	3.3nF	Closed	Waveform at Pin 2

NOTES:

7. The hi and lo frequencies can be obtained by connecting pin 8 to pin 7 (f_{HI}) and then connecting pin 8 to pin 6 (f_{LO}). Otherwise apply Sweep Voltage at pin 8 ($^2/_3$ V_{SUPPLY} +2V) ≤ V_{SWEEP} ≤ V_{SUPPLY} where V_{SUPPLY} is the total supply voltage. In Figure 5B, pin 8 should vary between 5.3V and 10V with respect to ground.
8. 10V ≤ V+ ≤ 30V, or ±5V ≤ V_{SUPPLY} ≤ ±15V.
9. Oscillation can be halted by forcing pin 10 to +5V or -5V.
10. Output Amplitude is tested under static conditions by forcing pin 10 to 5V then to -5V.
11. Not tested; for design purposes only.

Test Circuit

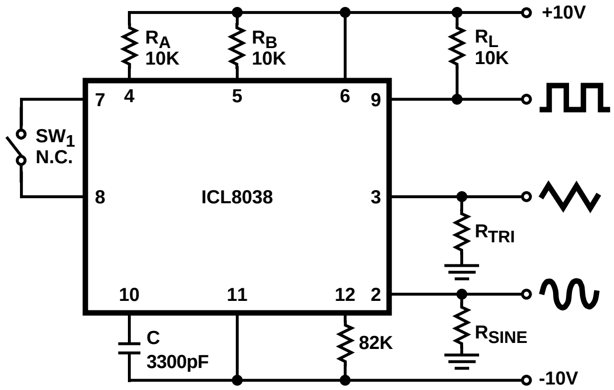
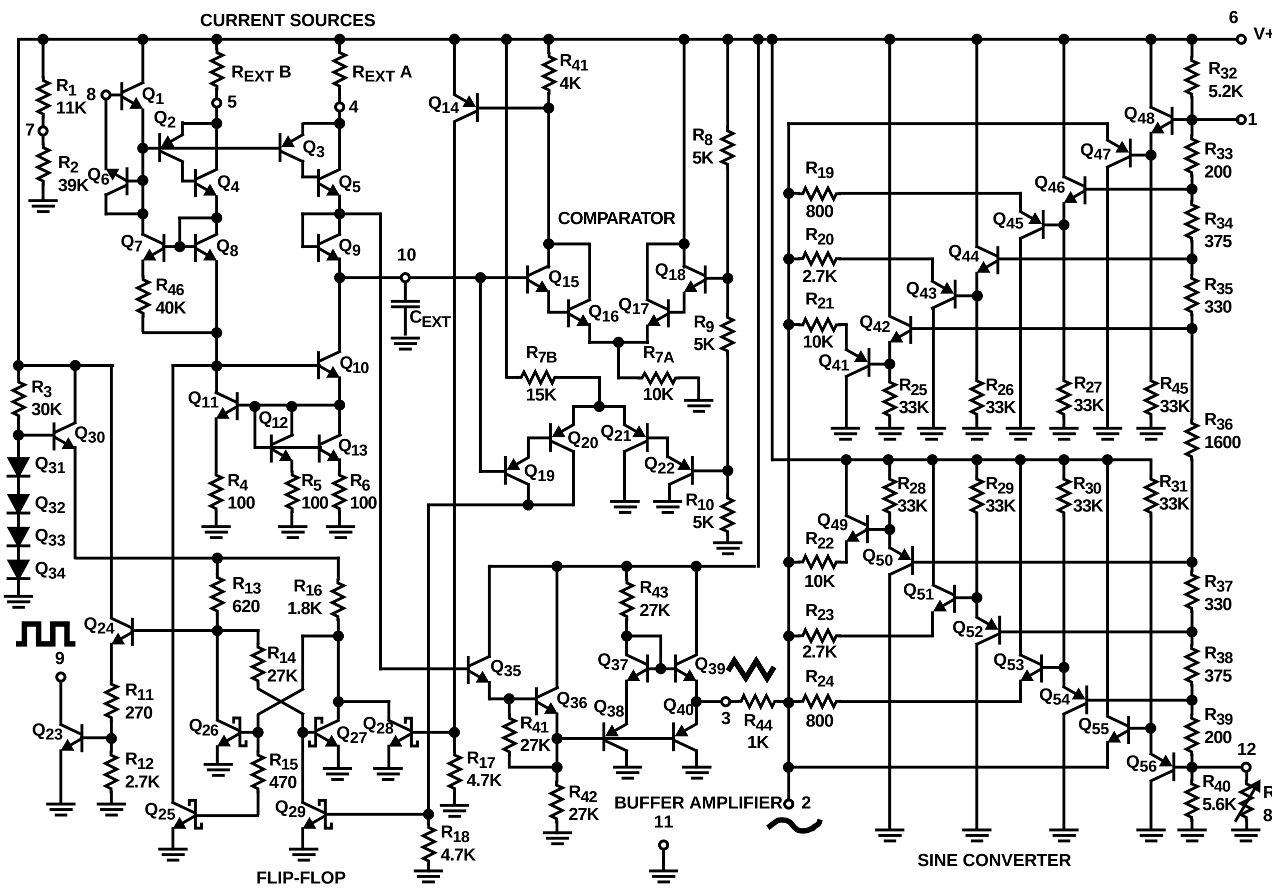


FIGURE 1. TEST CIRCUIT

Detailed Schematic



Application Information (See Functional Diagram)

An external capacitor C is charged and discharged by two current sources. Current source #2 is switched on and off by a flip-flop, while current source #1 is on continuously. Assuming that the flip-flop is in a state such that current source #2 is off, and the capacitor is charged with a current I, the voltage across the capacitor rises linearly with time. When this voltage reaches the level of comparator #1 (set at 2/3 of the supply voltage), the flip-flop is triggered, changes states, and releases current source #2. This current source normally carries a current 2I, thus the capacitor is discharged with a net-current I and the voltage across it drops linearly with time. When it has reached the level of comparator #2 (set at 1/3 of the supply voltage), the flip-flop is triggered into its original state and the cycle starts again.

Four waveforms are readily obtainable from this basic generator circuit. With the current sources set at I and 2I respectively, the charge and discharge times are equal. Thus a triangle waveform is created across the capacitor and the flip-flop produces a square wave. Both waveforms are fed to buffer stages and are available at pins 3 and 9.

The levels of the current sources can, however, be selected over a wide range with two external resistors. Therefore, with the two currents set at values different from I and 2I, an asymmetrical sawtooth appears at Terminal 3 and pulses with a duty cycle from less than 1% to greater than 99% are available at Terminal 9.

The sine wave is created by feeding the triangle wave into a nonlinear network (sine converter). This network provides a decreasing shunt impedance as the potential of the triangle moves toward the two extremes.

Waveform Timing

The *symmetry* of all waveforms can be adjusted with the external timing resistors. Two possible ways to accomplish this are shown in Figure 3. 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 1 state of the square wave.

The magnitude of the triangle waveform is set at $^1/_3$ V_{SUPPLY}; therefore the rising portion of the triangle is,

$$t_1 = \frac{C \times V}{I} = \frac{C \times 1/3 \times V_{SUPPLY} \times R_A}{0.22 \times V_{SUPPLY}} = \frac{R_A \times C}{0.66}$$

The falling portion of the triangle and sine wave and the 0 state of the square wave is:

$$t_2 = \frac{C \times V}{1} = \frac{C \times 1/3 V_{SUPPLY}}{2(0.22)\frac{V_{SUPPLY}}{R_B} - 0.22\frac{V_{SUPPLY}}{R_A}} = \frac{R_A R_B C}{0.66(2R_A - R_B)}$$

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 3B is slightly more convenient. A 1kΩ potentiometer may not allow the duty cycle to be adjusted through 50% on all devices. If a 50% duty cycle is required, a 2kΩ or 5kΩ potentiometer should be used.

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

$$f = \frac{1}{t_1 + t_2} = \frac{1}{\frac{R_A C}{0.66}\left(1 + \frac{R_B}{2R_A - R_B}\right)}$$

or, if $R_A = R_B = R$

$$f = \frac{0.33}{RC} \text{ (for Figure 3A)}$$

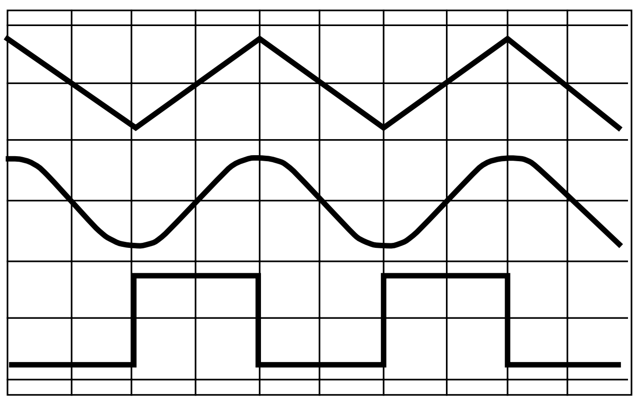


FIGURE 2A. SQUARE WAVE DUTY CYCLE - 50%

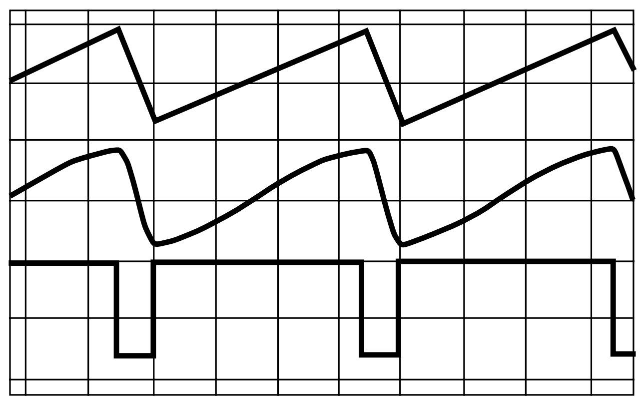


FIGURE 2B. SQUARE WAVE DUTY CYCLE - 80%

FIGURE 2. PHASE RELATIONSHIP OF WAVEFORMS

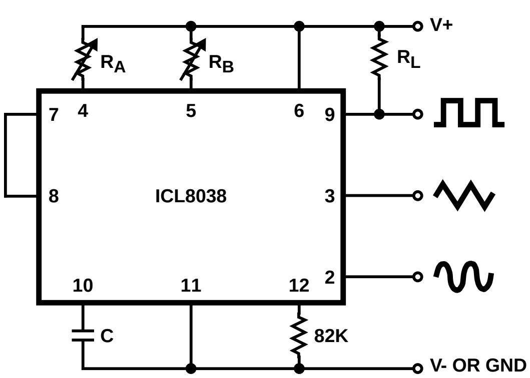


FIGURE 3A.

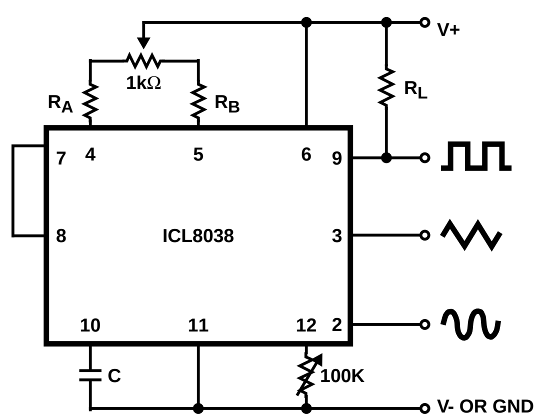


FIGURE 3B.

FIGURE 3. POSSIBLE CONNECTIONS FOR THE EXTERNAL TIMING RESISTORS

Neither time nor frequency are dependent on 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 functions of the supply voltage and thus their effects cancel.

Reducing Distortion

To minimize sine wave distortion the 82kΩ resistor between pins 11 and 12 is best made variable. With this arrangement distortion of less than 1% is achievable. To reduce this even further, two potentiometers can be connected as shown in Figure 4; this configuration allows a typical reduction of sine wave distortion close to 0.5%.

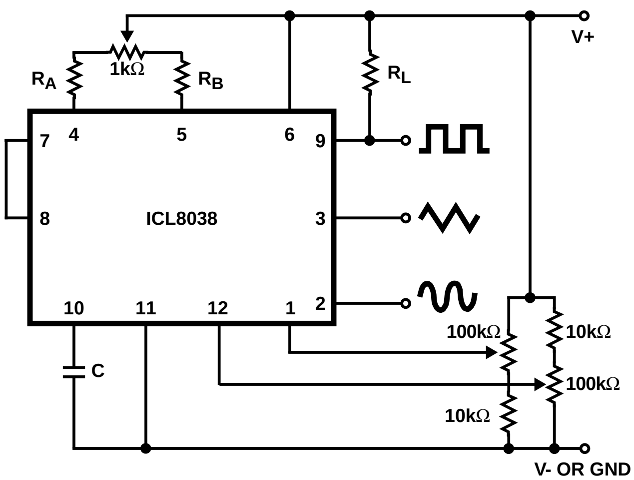


FIGURE 4. CONNECTION TO ACHIEVE MINIMUM SINE WAVE DISTORTION

Selecting R_A, R_B and C

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 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 larger errors. Optimum performance will, therefore, be obtained with charging currents of 10µA to 1mA. If pins 7 and 8 are shorted together, the magnitude of the charging current due to R_A can be calculated from:

$$I = \frac{R_1 \times (V+ - V-)}{(R_1 + R_2)} \times \frac{1}{R_A} = \frac{0.22(V+ - V-)}{R_A}$$

R_1 and R_2 are shown in the Detailed Schematic.

A similar calculation holds for R_B.

The capacitor value should be chosen at the upper end of its possible range.

Waveform Out Level Control and Power Supplies

The waveform generator can be operated either from a single power supply (10V to 30V) or a dual power supply (±5V to ±15V). 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+ 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 can be made TTL compatible (load resistor connected to +5V) while the waveform generator itself is powered from a much higher voltage.

Frequency Modulation and Sweeping

The frequency of the waveform generator is a direct function of the DC voltage at Terminal 8 (measured from V+). By altering this voltage, frequency modulation is performed. For small deviations (e.g. ±10%) the modulating signal can be applied directly to pin 8, merely providing DC decoupling with a capacitor as shown in Figure 5A. An external resistor between pins 7 and 8 is not necessary, but it can be used to increase input impedance from about 8kΩ (pins 7 and 8 connected together), to about (R + 8kΩ).

For larger FM deviations or for frequency sweeping, the modulating signal is applied between the positive supply voltage and pin 8 (Figure 5B). 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 created (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 down from V+ by ($^1/_3$ V_{SUPPLY} - 2V).

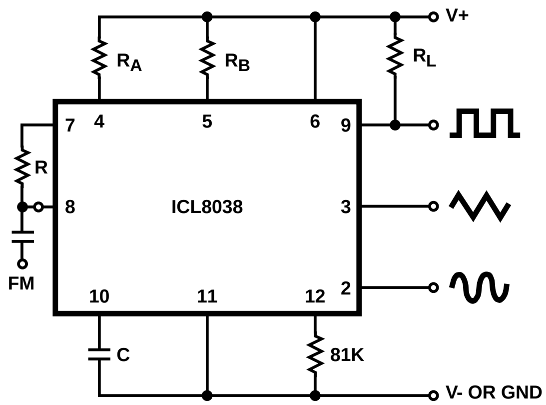


FIGURE 5A. CONNECTIONS FOR FREQUENCY MODULATION

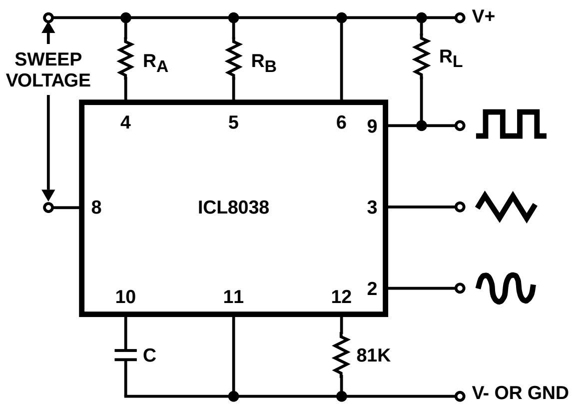


FIGURE 5B. CONNECTIONS FOR FREQUENCY SWEEP

FIGURE 5.

Typical Applications

The sine wave output has a relatively high output impedance (1kΩ Typ). The circuit of Figure 6 provides buffering, gain and amplitude adjustment. A simple op amp follower could also be used.

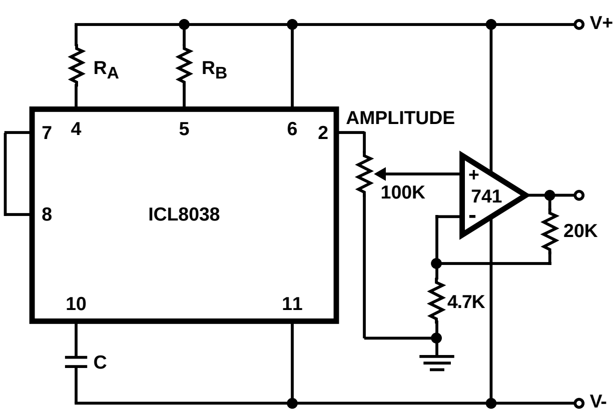


FIGURE 6. SINE WAVE OUTPUT BUFFER AMPLIFIERS

With a dual supply voltage the external capacitor on Pin 10 can be shorted to ground to halt the ICL8038 oscillation. Figure 7 shows a FET switch, diode ANDed with an input strobe signal to allow the output to always start on the same slope.

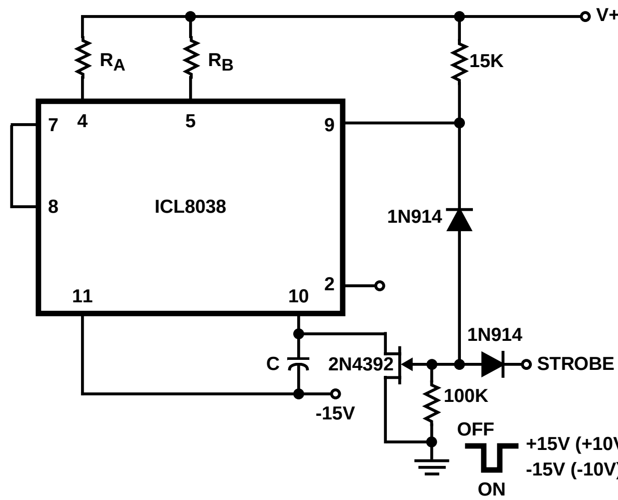


FIGURE 7. STROBE TONE BURST GENERATOR

To obtain a 1000:1 Sweep Range on the ICL8038 the voltage across external resistors R_A and R_B must decrease to nearly zero. This requires that the highest voltage on control Pin 8 exceed the voltage at the top of R_A and R_B by a few hundred mV. The Circuit of Figure 8 achieves this by using a diode to lower the effective supply voltage on the ICL8038. The large resistor on pin 5 helps reduce duty cycle variations with sweep.

The linearity of input sweep voltage versus output frequency can be significantly improved by using an op amp as shown in Figure 10.

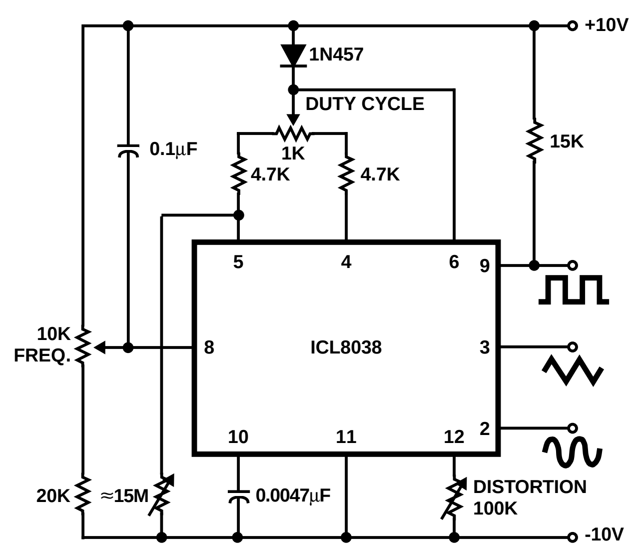


FIGURE 8. VARIABLE AUDIO OSCILLATOR, 20Hz TO 20kHzY

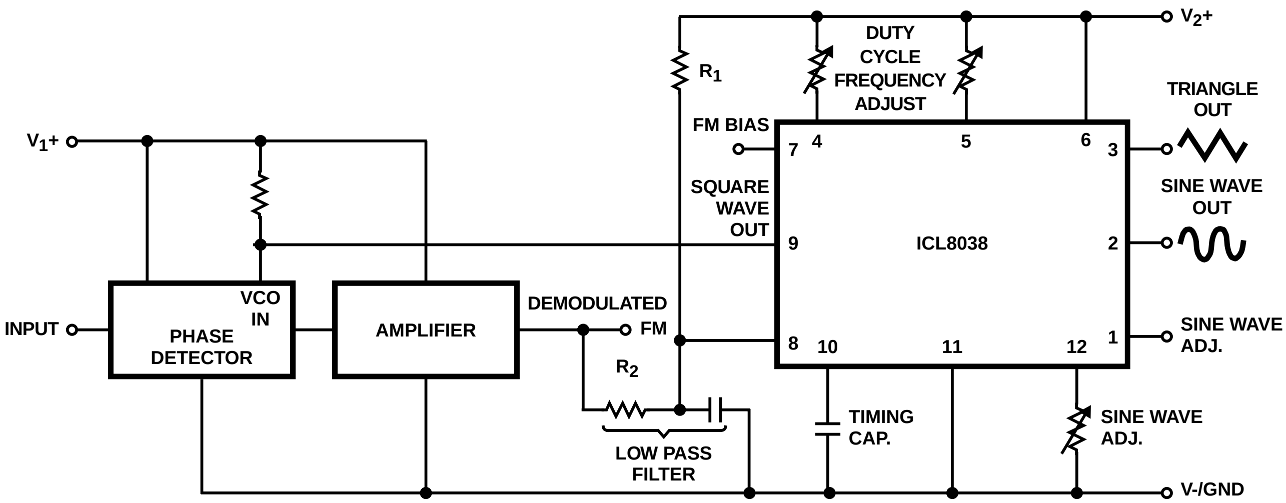


FIGURE 9. WAVEFORM GENERATOR USED AS STABLE VCO IN A PHASE-LOCKED LOOP

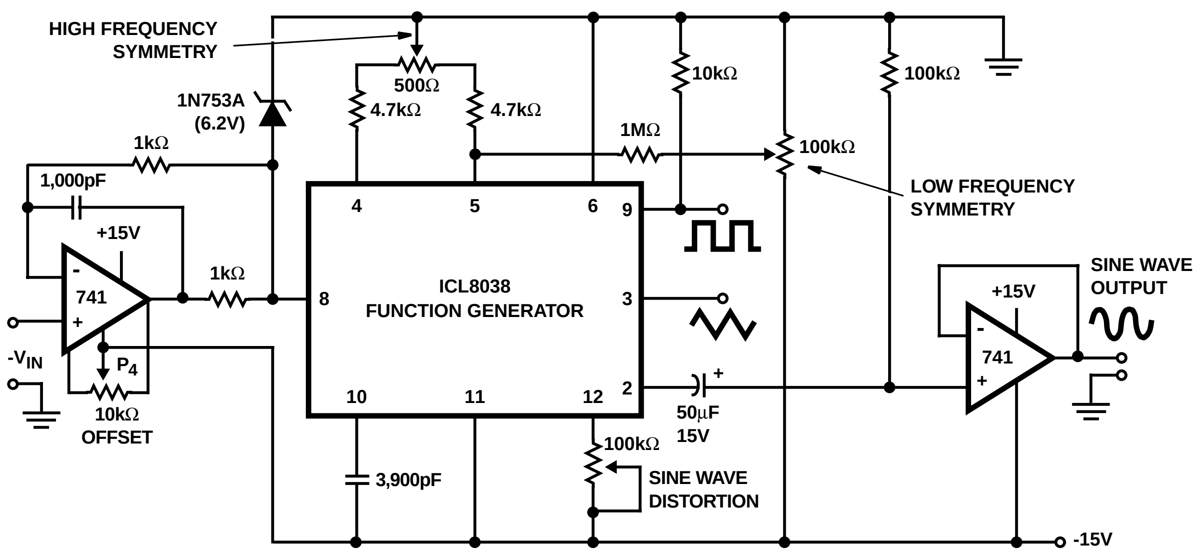


FIGURE 10. LINEAR VOLTAGE CONTROLLED OSCILLATOR

Use in Phase Locked Loops

Its high frequency stability makes the ICL8038 an ideal building block for a phase locked loop as shown in Figure 9. In this application the remaining functional blocks, the phase detector and the amplifier, can be formed by a number of available ICs (e.g., MC4344, NE562).

In order to match these building blocks to each other, two steps must be taken. First, two different supply voltages are used and the square wave output is returned to the supply of the phase detector. This assures that the VCO input voltage will not exceed the capabilities of the phase detector. If a smaller VCO signal is required, a simple resistive voltage divider is connected between pin 9 of the waveform generator and the VCO input of the phase detector.

Second, the DC output level of the amplifier must be made compatible to the DC level required at the FM input of the waveform generator (pin 8, 0.8V+). The simplest solution here is to provide a voltage divider to V+ (R_1, R_2 as shown) if the amplifier has a lower output level, or to ground if its level is higher. The divider can be made part of the low-pass filter.

This application not only provides for a free-running frequency with very low temperature drift, but is also has the unique feature of producing a large reconstituted sinewave signal with a frequency identical to that at the input.

For further information, see Harris Application Note AN013, “Everything You Always Wanted to Know About the ICL8038”.

Definition of Terms

Supply Voltage (V_{SUPPLY})**.** The total supply voltage from V+ to V-.

Supply Current. The supply current required from the power supply to operate the device, excluding load currents and the currents through R_A and R_B.

Frequency Range. The frequency range at the square wave output through which circuit operation is guaranteed.

Sweep FM Range. The ratio of maximum frequency to minimum frequency which can be obtained by applying a sweep voltage to pin 8. For correct operation, the sweep voltage should be within the range:

$(^2/_3\ V_{SUPPLY} + 2V) < V_{SWEEP} < V_{SUPPLY}$

FM Linearity. The percentage deviation from the best fit straight line on the control voltage versus output frequency curve.

Output Amplitude. The peak-to-peak signal amplitude appearing at the outputs.

Saturation Voltage. The output voltage at the collector of Q_{23} when this transistor is turned on. It is measured for a sink current of 2mA.

Rise and Fall Times. The time required for the square wave output to change from 10% to 90%, or 90% to 10%, of its final value.

Triangle Waveform Linearity. The percentage deviation from the best fit straight line on the rising and falling triangle waveform.

Total Harmonic Distortion. The total harmonic distortion at the sine wave output.

Typical Performance Curves

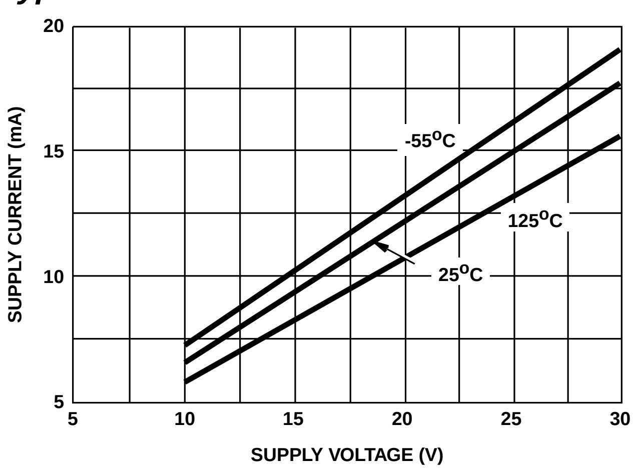


FIGURE 11. SUPPLY CURRENT vs SUPPLY VOLTAGE

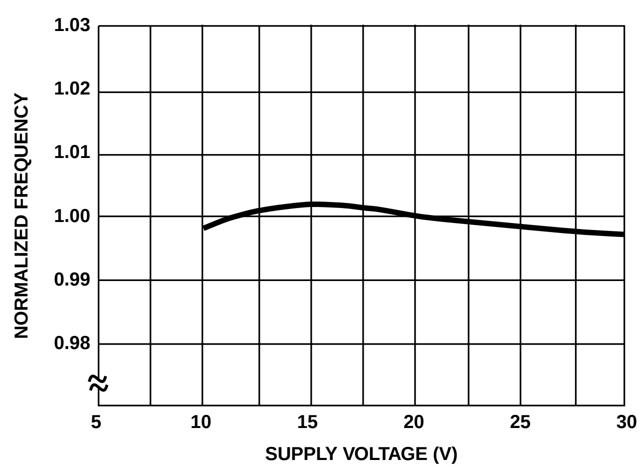


FIGURE 12. FREQUENCY vs SUPPLY VOLTAGE

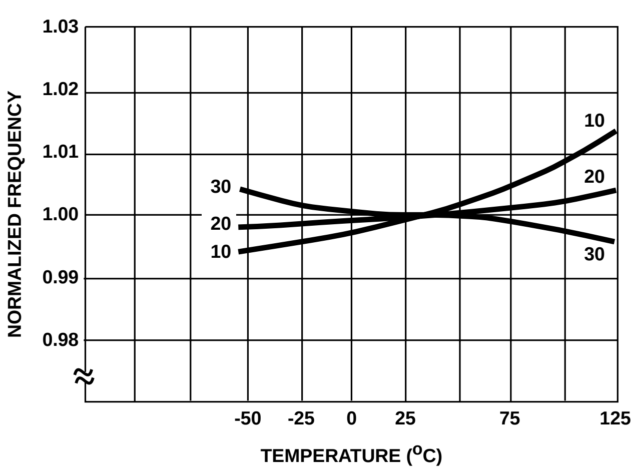


FIGURE 13. FREQUENCY vs TEMPERATURE

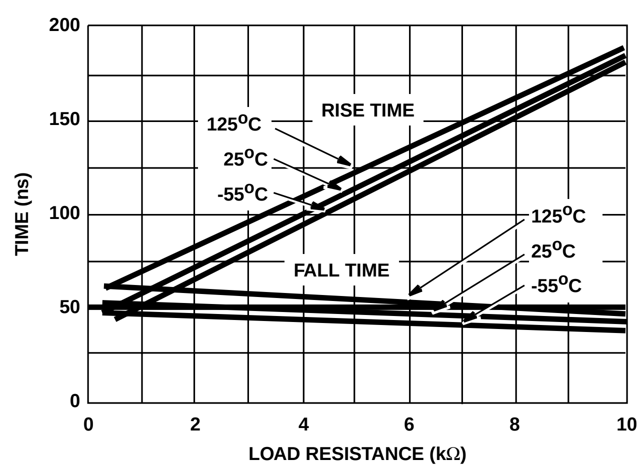


FIGURE 14. SQUARE WAVE OUTPUT RISE/FALL TIME vs LOAD RESISTANCE

Typical Performance Curves (Continued)

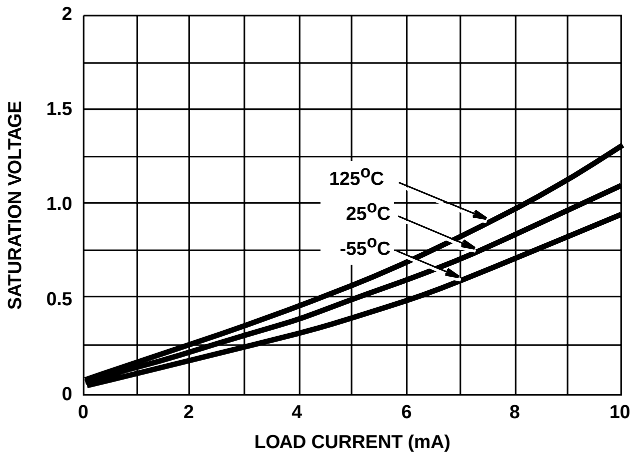


FIGURE 15. SQUARE WAVE SATURATION VOLTAGE vs LOAD CURRENT

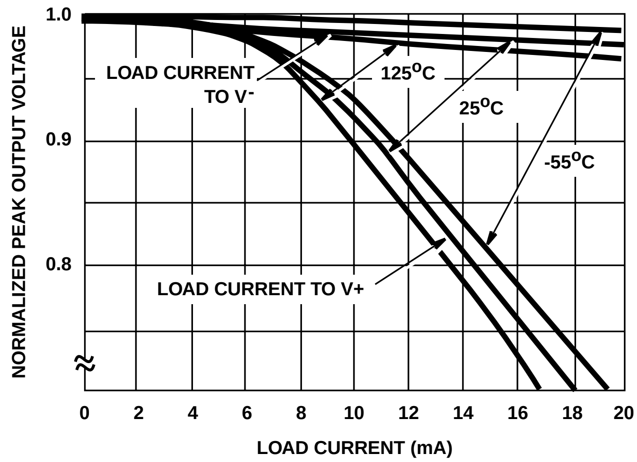


FIGURE 16. TRIANGLE WAVE OUTPUT VOLTAGE vs LOAD CURRENT

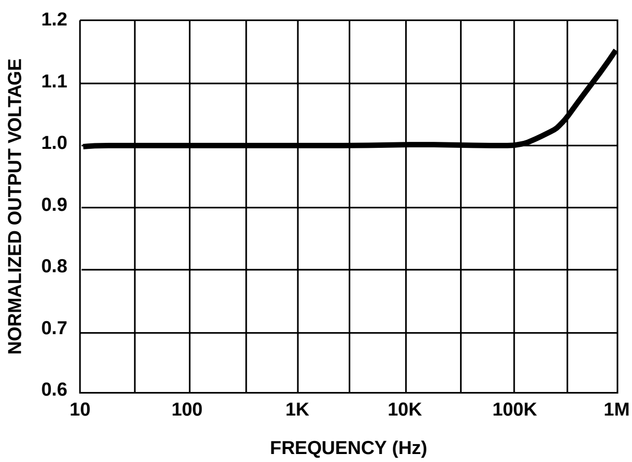


FIGURE 17. TRIANGLE WAVE OUTPUT VOLTAGE vs FREQUENCY

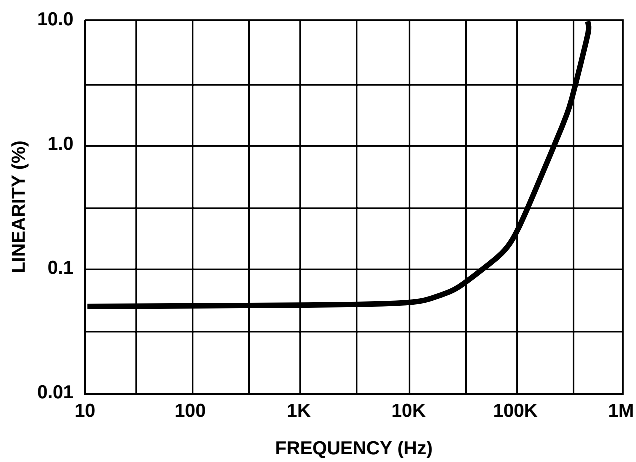


FIGURE 18. TRIANGLE WAVE LINEARITY vs FREQUENCY

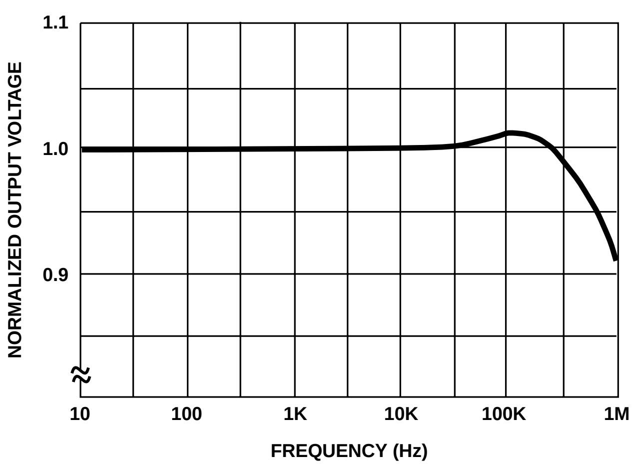


FIGURE 19. SINE WAVE OUTPUT VOLTAGE vs FREQUENCY

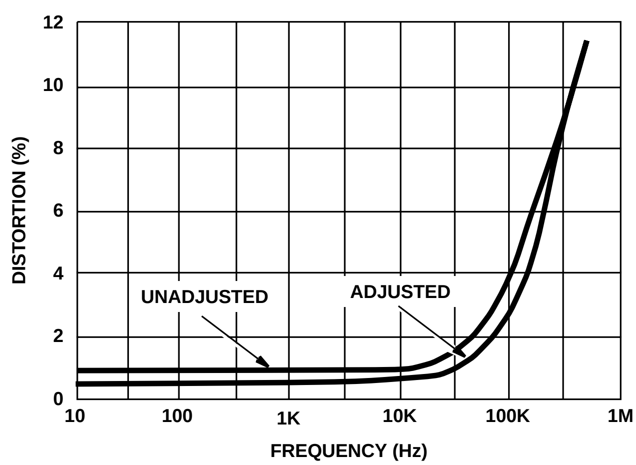


FIGURE 20. SINE WAVE DISTORTION vs FREQUENCY

Everything You Always Wanted to Know About the ICL8038

Application Note | November 199 | AN013.1

Author: Bill O'Neil

Introduction

The 8038 is a function generator capable of producing sine, square, triangular, sawtooth and pulse waveforms (some at the same time). Since its introduction, marketing and application engineers have been manning the phones explaining the care and feeding of the 8038 to customers worldwide. This experience has enabled us to form articulate responses to the most frequently asked questions. So, with data sheet and breadboard in hand, read on and be enlightened.

Question 1

I want to sweep the frequency externally but can only get a range of 100:1 (or 50:1, or 10:1). Your data sheet says 1000:1. How much sweep range can I expect?

Answer

Let's look at what determines the output frequency. Start by examining the circuit schematic at pin 8 in the upper left hand corner. From pin 8 to pin 5 we have the emitter-base of NPN Q_1 and the emitter-base of PNP Q_2. Since these two diode drops cancel each other (approximately), the potential at pins 8, 5, and 4 are the same. This means that the voltage from V+ to pin 8 is the same as the voltage across external resistors R_A and R_B. This is a textbook example of a voltage across two resistors which produce two currents to charge and discharge a capacitor between two fixed voltages. This is also a linear system. If the voltage across the resistors is dropped from 10V to 1V, the frequency will drop by 10:1. Changing from 1V to 0.1V will also change the frequency by 10:1. Therefore, by causing the voltage across the external resistors to change from say 10V to 10mV, the frequency can be made to vary at least 1000:1. There are, however, several factors which make this large sweep range less than ideal.

Question 2

You say I can vary the voltage on pin 8 (FM sweep input) to get this large range, yet when I short pin 8 to V+ (pin 6), the ratio is only around 100:1.

Answer

This is often true. With pin 8 shorted to V+, a check on the potentials across the external R_A and R_B will show 100mV or more. This is due to the V_{BE} mismatch between Q_1 and Q_2 (also Q_1 and Q_3) because of the geometries and current levels involved. Therefore, to get smaller voltages across these resistors, pin 8 must be raised above V+.

Question 3

How can I raise pin 8 above V+ without a separate power supply?

Answer

First of all, the voltage difference need only be a few hundred millivolts so there is no danger of damaging the 8038. One way to get this higher potential is to lower the supply voltage on the 8038 and external resistors. The simplest way to do this is to include a diode in series with pin 6 and resistors R_A and R_B. See Figure 1. This technique should increase the sweep range to 1000:1.

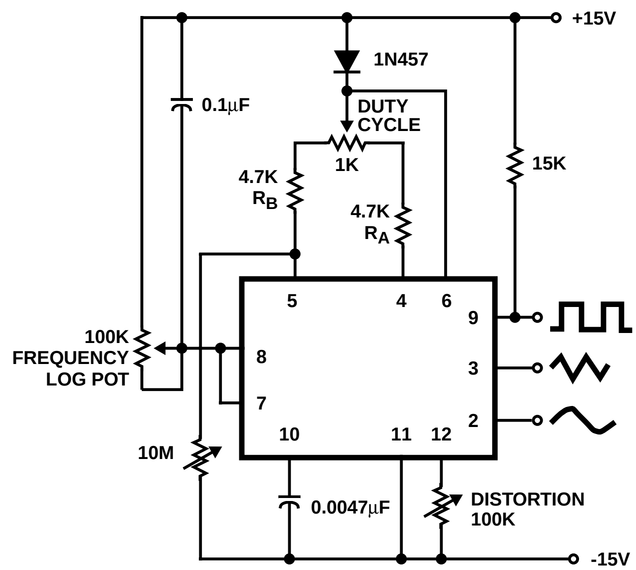


FIGURE 1. VARIABLE AUDIO OSCILLATOR, 20Hz TO 20kHz

Question 4

O.K., now I can get a large frequency range, but I notice that the duty cycle and hence my distortion changes at the lowest frequencies.

Answer

This is caused partly by a slight difference in the V_{BE}s of Q_2 and Q_3. In trying to manufacture two identical transistors, it is not uncommon to get V_{BE} differences of several millivolts or more. In the standard 8038 connection with pins 7 and 8 connected together, there are several volts across R_A and R_B and this small mismatch is negligible. However, in a swept mode with the voltage at pin 8 near V+ and only tens of millivolts across R_A and R_B, the V_{BE} mismatch causes a larger mismatch in charging currents, hence the duty cycle changes. For lowest distortion then, it is advisable to keep the minimum voltage across R_A and R_B around 100mV. This would of course, limit the frequency sweep range to around 100:1.

Question 5

I have a similar duty cycle problem when I use high values of R_A and R_B. What causes this?

Answer

There is another error term which becomes important at very low charge and discharge currents. This error current is the emitter current of Q_7. The application note on the 8038 gives a complete circuit description, but it is sufficient to know that the current charging the capacitor is the current in R_A which flows down through diode Q_9 and into the external C. The discharge current is the current in R_B which flows down through diode Q_8. Adding to the Q_8 current is the current of Q_7 which is only a few microamperes. Normally, this Q_7 current is negligible, but with a small current in R_B, this current will cause a faster discharge than would be expected. This problem will also appear in sweep circuits when the voltage across the external resistors is small.

Question 6

How can I get the lowest distortion over the largest frequency sweep range.

Answer

First of all, use the largest supply voltage available (±15V or +30V is convenient). This will minimize V_{BE} mismatch problems and allow a wide variation of voltage on pin 8. The potential on pin 8 may be swept from V_{CC} (and slightly higher) to 2/3 V_{CC} +2V) where V_{CC} is the total voltage across the 8038. Specifically for ±15V supplies (+30V), the voltage across the external resistors can be varied from 0V to nearly 8V before clipping of the triangle waveform occurs.

Second, keep the maximum currents relatively large (1mA or 2mA) to minimize the error due to Q_7. Higher currents could be used, but the small geometry transistors used in the 8038 could give problems due to $V_{CE(SAT)}$ and bulk resistance, etc.

Third, and this is important, use two separate resistors for R_A and R_B rather than one resistor with pins 4 and 5 connected together. This is because transistors Q_2 and Q_3 form a differential amplifier whose gain is determined by the impedance between pins 4 and 5 as well as the quiescent current. There are a number of implications in the differential amplifier connection (pins 4 and 5 shorted). The most obvious is that the gain determines the way the currents split between Q_2 and Q_3. Therefore, any small offset or differential voltage will cause a marked imbalance in the charge and discharge currents and hence the duty cycle. A more subtle result of this connection is the effective capacitance at pin 10. With pins 4 and 5 connected together, the "Miller Effect" as well as the compound transistor connection of Q_3 and Q_5 can produce several hundred picofarads at pin 10, seriously limiting the highest frequency of oscillation. The effective capacitance would have to be considered important in determining what value of external C would result in a particular frequency of oscillation. The single resistor connection is fine for very simple circuits, but where performance is critical, the two separate resistors for R_A and R_B are recommended.

Finally, trimming the various pins for lowest distortion deserves some attention. With pins 7 and 8 connected together and the pot at pin 7 and 8 externally set at its maximum, adjust the ratio of R_A and R_B for 50% duty cycle. Then adjust a pot on pin 12 or both pins 1 and 12 depending on minimum distortion desired. After these trims have been made, set the voltage on pin 8 for the lowest frequency of interest. The principle error here is due to the excess current of Q_7 causing a shift in the duty cycle. This can be partially compensated for by bleeding a small current away from pin 5. The simplest way to do this is to connect a high value of resistance (10MΩ to 20MΩ) from pin 5 to V- to bring the duty cycle back to 50%. This should result in a reasonable compromise between low distortion and large sweep range.

Question 7

This waveform generator is a piece of junk. The triangle wave is non-linear and has large glitches when it changes slope.

Answer

You're probably having trouble keeping the constant voltage across R_A and R_B really constant. The pulse output on pin 9 puts a moderate load on both supplies as it switches current on and off. Changes in the supply reflect as variations in charging current, hence non-linearity. Decoupling both power supply pins to ground right at the device pins is a good idea. Also, pins 7 and 8 are susceptible to picking up switching transients (this is especially true on printed circuit boards where pins 8 and 9 run side by side). Therefore, a capacitor (0.1µF or more) from V+ to pin 8 is often advisable. In the case when the pulse output is not required, leave pin 9 open to be sure of minimizing transients.

Question 8

What is the best supply voltage to use for lowest frequency drift with temperature?

Answer

The 8038AM, 8038AC, 8038BM and 8038BC are all temperature drift tested at V_{CC} = +20V (or ±10V). A curve in the lower right hand corner of Page 4 of the data sheet indicates frequency versus temperature at other supply voltages. It is important to connect pins 7 and 8 together.

Question 9

Why does connecting pin 7 to pin 8 give the best temperature performance?

Answer

There is a small temperature drift of the comparator thresholds in the 8038. To compensate for this, the voltage divider at pin 7 uses thin film resistors plus diffused resistors. The different temperature coefficients of these resistors causes the voltage at pins 7 and 8 to vary 0.5mV/^{o}C to maintain overall low frequency drift at V_{CC} = 20V. At higher supply voltages, e.g., ±15V (+30V), the threshold drifts are smaller compared with the total supply voltage. In this case, an externally applied constant voltage at pin 8 will give reasonably low frequency drift with temperature.

Question 10

Your data sheet is very confusing about the phase relationship of the various waveforms.

Answer

Sorry about that! The thing to remember is that the triangle and sine wave must be in phase since one is derived from the other. A check on the way the circuit works shows that the pulse waveform on pin 9 will be high as the capacitor charges (positive slope on the triangle wave) and will be low during discharge (negative slope on the triangle wave).

The latest data sheet corrects the photograph Figure 7 on Page 5 of the data sheet. The 20% duty cycle square wave was inverted, i.e., should be 80% duty cycle. Also, on that page under "Waveform Timing" the related sentences should read "R_A controls the rising portion of the triangle and sine-wave and the 1 state of the square wave." Also, "the falling portion of the triangle and sine wave and the 0 state of the square wave is:"

Question 11

Under Parameter Test Conditions on Page 3 of your 8038 data sheet, the suggested value for Min and Max duty cycle adjust don't seem to work.

Answer

The positive charging current is determined by R_A alone since the current from R_B is switched off. (See 8038 Application Note AN012 for complete circuit description.) The negative discharge current is the ***difference*** between the R_A current and twice the R_B current. Therefore, changing R_B will affect only the discharge time, while changing R_A will affect both charge and discharge times. For short negative going pulses (greater than 50% duty cycle) we can lower the value of R_B (e.g., R_A = 50kΩ and R_B = 1.6kΩ). For short positive going pulses (duty cycles less than 50%) the limiting values are reached when the current in R_A is twice that in R_B (e.g., R_B = 50kΩ). This has been corrected on the latest data sheet.

Question 12

I need to switch the waveforms off and on. What's a good way to strobe the 8038?

Answer

With a dual supply voltage (e.g., ±15V) the external capacitor (pin 10) can be shorted to ground so that the sine wave and triangle wave always begin at a zero crossing point. Random switching has a 50/50 chance of starting on a positive or negative slope. A simple AND gate using pin 9 will allow the strobe to act only on one slope or the other, see Figure 2. Using only a single supply, the capacitor (pin 10) can be switched either to V+ or ground to force the comparator to set in either the charge or discharge mode. The disadvantage of this technique is that the beginning cycle of the next burst will be 30% longer than the normal cycle.

Question 13

How can I buffer the sine wave output without loading it down?

Answer

The simplest circuit is a simple op amp follower as shown in Figure 3A. Another circuit shown in Figure 3B allows amplitude and offset controls without disturbing the 8038. Either circuit can be DC or AC coupled. For AC coupling the op amp non-inverting input must be returned to ground with a 100kΩ resistor.

Question 14

Your 8038 data sheet implies that all waveforms can operate up to 1MHz. Is this true?

Answer

Unfortunately, only the square wave output is useful at that frequency. As can be seen from the curves on page 4 of the data sheet, distortion on the sine wave and linearity of the triangle wave fall off rapidly above 200kHz.

Question 15

Is it normal for this device to run hot to the touch?

Answer

Yes. The 8038 is essentially resistive. The power dissipation is then E^2/R and at ±15V, the device does run hot. Extensive life testing under this operating condition and maximum ambient temperature has verified the reliability of this product.

Question 16

How stable are the output amplitudes versus temperature?

Answer

The amplitude of the triangle waveform decreases slightly with temperature. The typical amplitude coefficient is -0.01%/^{o}C, giving a drop of about 1% at 125^{o}C. The sine output is less sensitive and decreases only about 0.6% at 125^{o}C. For the square wave output the $V_{CE(SAT)}$ goes from 0.12V at 25^{o}C to 0.17V at 125^{o}C. Leakage current in the "1" state is less than a few nanoamperes even at 125^{o}C and is usually negligible.

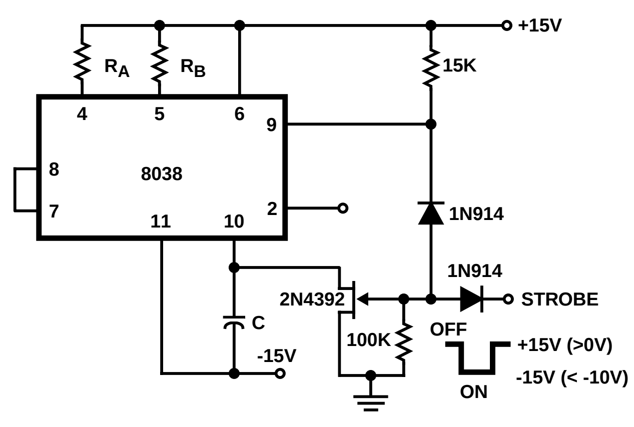


FIGURE 2. STROBE-TONE BURST GENERATOR

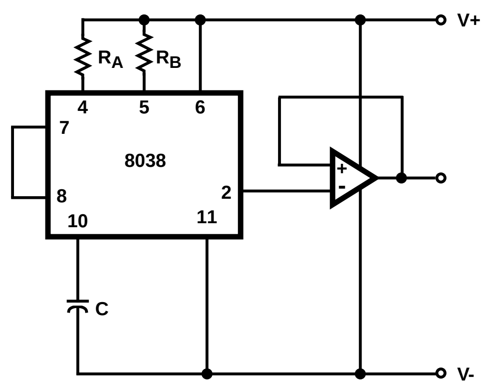


FIGURE 3A.

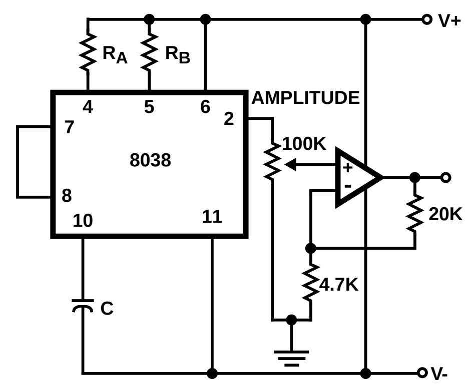


FIGURE 3B.

FIGURE 3. SINEWAVE OUTPUT BUFFER AMPLIFIERS

Schematic Diagram