



WIDE RANGE FUNCTION GENERATOR

The sine, square, triangle function generator has proven to be exceptionally useful. Various IC circuits have been published for generating square and triangle waveforms in an attempt to duplicate the general purpose function generator. However, these simple circuits are usually limited to about 10 kHz and have no sine wave output. The function generator shown here provides all three waveforms and operates from below 10 Hz to 1 MHz with usable output to about 2 MHz.

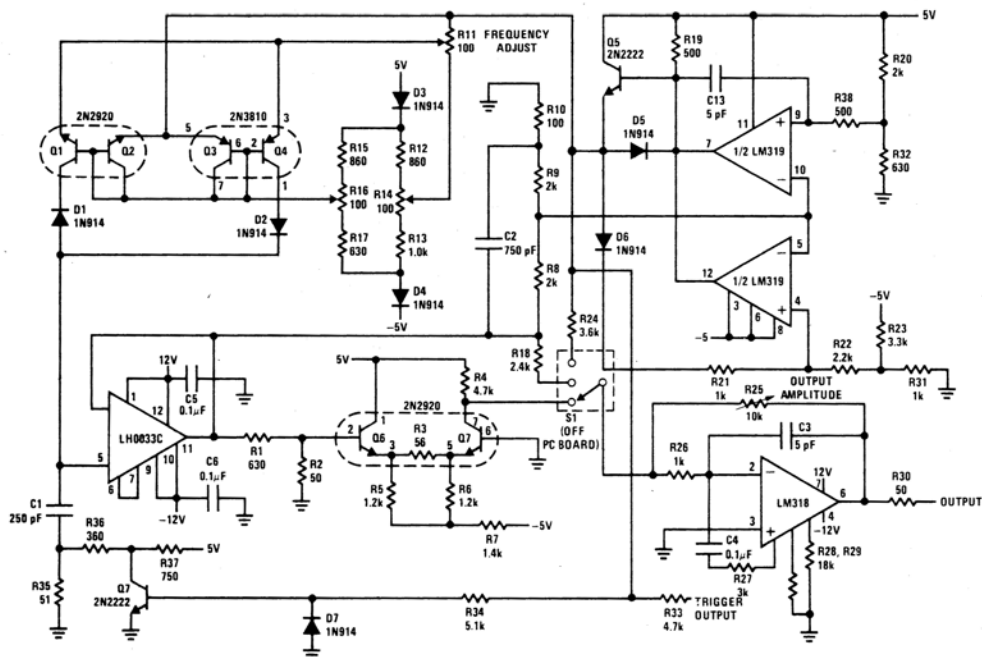
DESIGN

As with most function generators, an integrator-comparator generates the square and triangle waveforms with a shaping circuit forming the triangle wave into a sine wave.

Obtaining six decades of operating with a single control plus 2 MHz operation requires some unusual circuit

design techniques as well as good high frequency IC's. The triangle wave is generated by switching current-source transistors to alternately charge and discharge the timing capacitor. This generates a linear tri-wave without the use of an op amp integrator. A FET voltage follower buffers the tri-wave and drives the comparator, output amplifier and sine converter.

A precision dual comparator is used to set the peak-to-peak amplitude of the tri-wave. It is necessary to accurately control the tri-wave since the sine converter requires close amplitude control to produce a low distortion output. An accurate divider across the 5V supply regulators sets the threshold at the inputs of the LM319 comparators. The tri-wave is applied to the other comparator inputs through another divider—R8, R9, R10 and C2. The comparator switches when the amplitude of the tri-wave is $\pm 2.5V$. Capacitor C2 compensates for delays in the comparator at high frequencies.



Function Generator Schematic

PARTS LIST

R1	630Ω	1%	C1	250 pF	
R2	50Ω	1%	C2	750 pF	
R3	56Ω	5%	C3	5 pF	
R4	4.7k	5%	C4	0.1μF	
R5	1.2k	1%	C5	0.1μF	
R6	1.2k	1%	C6	0.1μF	
R7	1.4k	1%	C7	500μF	25V
R8	2k	5%	C8	500μF	25V
R9	2k	5%	C9	4.7μF	Solid Tantalum
R10	100Ω	5%	C10	4.7μF	Solid Tantalum
R11	100Ω potentiometer		C11	4.7μF	Solid Tantalum
R12	860Ω	5%	C12	4.7μF	Solid Tantalum
R13	1k	5%	C13	5 pF	
R14	100Ω PC mount trimpot				
R15	860Ω	5%			
R16	100Ω PC mount trimpot		Q1-Q2	2N2920	Dual NPN
R17	630Ω	5%	Q3-Q4	2N3810	Dual PNP
R18	2.4k	5%	Q5	2N2222	
R19	500Ω	5%	Q6-Q7	2N2920	Dual NPN
R20	2k	5%	Q8	2N2222	
R21	1k	5%			
R22	2.2k	5%	D1-D7	1N914	
R23	3.3k	5%	1-Varo VE27	Full Wave Bridge	
R24	3.6k	5%			
R25	10k potentiometer		1-LM318H	Operational Amplifier	
R26	1k	5%	1-LM319N	Dual Comparator	
R27	3k	5%	1-LH0033C	Fast Buffer	
R28	18k	5%	1-LM340K	12V Positive Voltage Regulator	
R29	18k	5%	1-LM320K	-12V Negative Voltage Regulator	
R30	50Ω	5%	1-LM309H	5V Positive Voltage Regulator	
R31	1k	5%	1-LM320H	-5V Negative Voltage Regulator	
R32	630Ω	5%			
R33	4.7k	5%	TI	Triad F90X	
R34	5.1k	5%			
R35	51Ω	5%	S ₁	3 Position ST Switch	
R36	360Ω	5%	S ₂	SPST Switch	
R37	750Ω	5%			
R38	500Ω	5%			

1/4 Amp Fuse and Holder—PC Board, Mounting Hardware, etc.

A square wave output from the comparator is obtained at the emitter of Q5 and is used to drive both the current switches and output amplifier. The current switches—Q1, Q2, Q3, Q4—provide a 5 nA to 5 mA current to timing capacitor, C1. The exponential relationship between emitter-base voltage and collector current allows a six decade current range to be obtained with a single potentiometer. The maximum output current is set by the current through R15 or R17 (depending on polarity) and appears when the arm of the frequency control, R11, ties all four emitters together. As R11 is rotated, a voltage is developed between the emitters of Q1—Q4 and Q2—Q3. This voltage decreases the emitter base voltage of Q1 and Q4 decreasing their operating current. About 380 mV is developed across R11 and corresponds to over a 10⁶ reduction in charging current.

Converting the tri-wave to a sine wave also uses the non-linear relationship between emitter-base voltage and collector current of a transistor pair.

Transistors Q6 and Q7 form a differential amplifier with emitter degeneration. The tri-wave is attenuated by R1 and R2 to about 450 mV and applied to one half of the pair—Q6. This drives the transistors non-linearly producing a sine wave output current at the collector of Q7 to drive the output amplifier.

The output amp, an LM318, uses feedforward compensation to maximize bandwidth and slew rate. It is used for adjustable scaling of all three waveforms to ±10V. Even with the feedforward, there is not quite enough bandwidth for good reproduction of the triangle or

square wave at frequencies over 1 MHz. Therefore, if the higher frequencies are of major interest, a faster output amplifier is necessary.

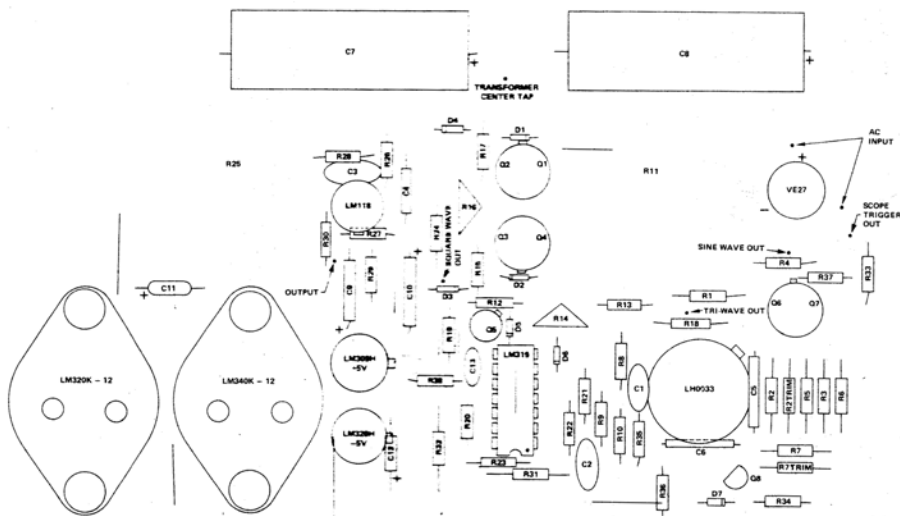
CONSTRUCTION AND SET UP

It is important to observe good construction practices for proper operation. All four power supplies should be bypassed with 4.7 μ F solid tantalum capacitors on the circuit board. Since the circuit operates at relatively high frequencies, short leads and a compact layout is a good idea. The wiring to the function selector switch should be made with shielded wire to minimize spikes from the fast square wave. At low frequencies, charging currents to the timing capacitor are quite low, so 60 Hz pickup can modulate the operating frequency. Shielding the current sources and C1 from the power transformer is in order.

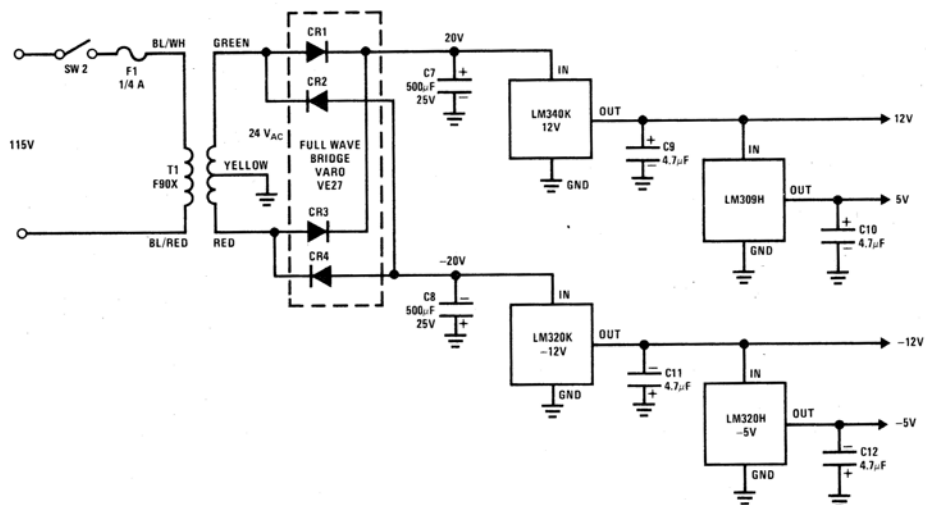
All transistors used to set the timing currents must track with temperature changes. Of course, the individual pairs will track but the NPN pair must also track the PNP pair as well. There are many small heat sinks for transistors which can be used to thermally couple Q1, Q2, to Q3, Q4. Temperature differences between the pair will cause the symmetry to change.

Set up is not difficult either. Firstly, R11 is set for a 1 MHz output. Then R16 is used to adjust the output symmetry. Secondly, R11 is set to provide a 10 Hz output and the symmetry is again adjusted by R14.

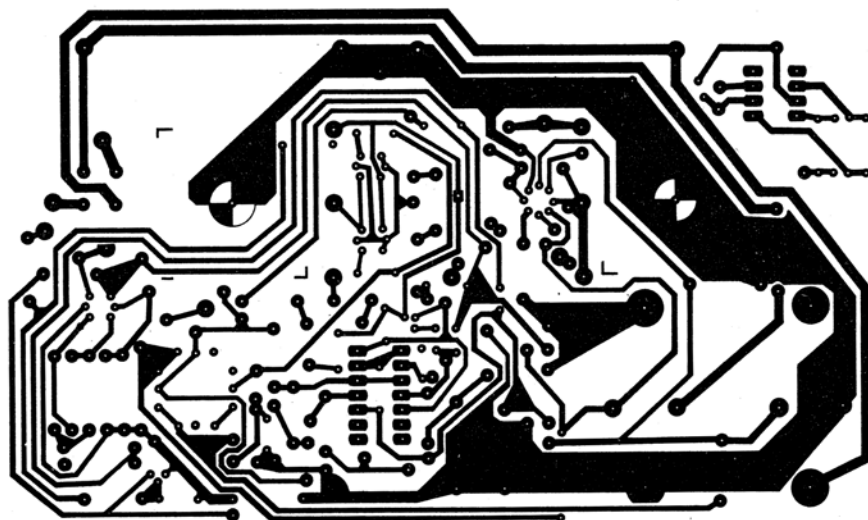
Other possible adjustments that may be necessary are in the sine converter. R7 can be trimmed if the sine output (from the LM318) has a dc offset. Also, it may be necessary to adjust R2 to minimize distortion. (It should be mentioned that there can be considerable distortion if the symmetry of the tri-wave is not 50%.)



Component Location, Top View



Power Supply Section Schematic



Circuit Board Layout
(This PC layout must be enlarged approximately 120% in order to be usable.)