# Wide Range Function Generator

National Semiconductor
Application Note 115

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.

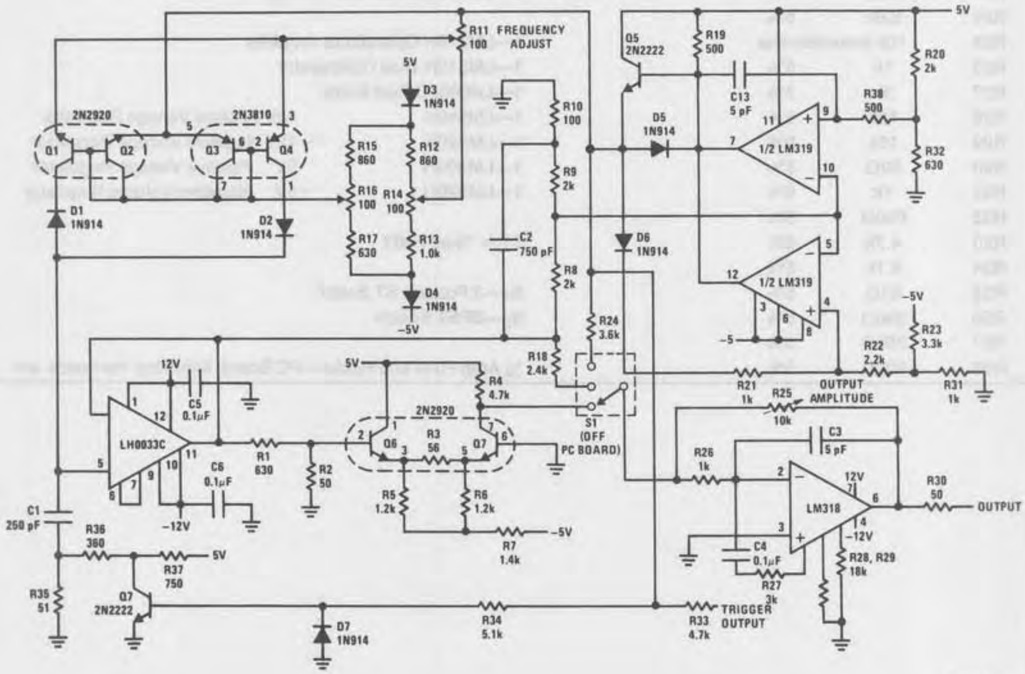
## DESIGN

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 comparator. 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 ±2.5V. Capacitor C2 compensates for delays in the comparator at high frequencies.

**Function Generator Schematic**

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**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 | 0.1 μF | |
| R5 | 1.2k | 1% | C5 | 0.1 μF | |
| R6 | 1.2k | 1% | C6 | 0.1 μF | |
| R7 | 1.4K | 1% | C7 | 500 μF | 25V |
| R8 | 2k | 5% | C8 | 500 μF | 25V |
| R9 | 2k | 5% | C9 | 4.7 μF | Solid Tantalum |
| R10 | 100Ω | 5% | C10 | 4.7 μF | Solid Tantalum |
| R11 | 100Ω potentiometer | | C11 | 4.7 μF | Solid Tantalum |
| R12 | 860Ω | 5% | C12 | 4.7 μF | 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% | T1 = 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% | ¼ 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 and 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 $10^6$ 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 $\pm$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.

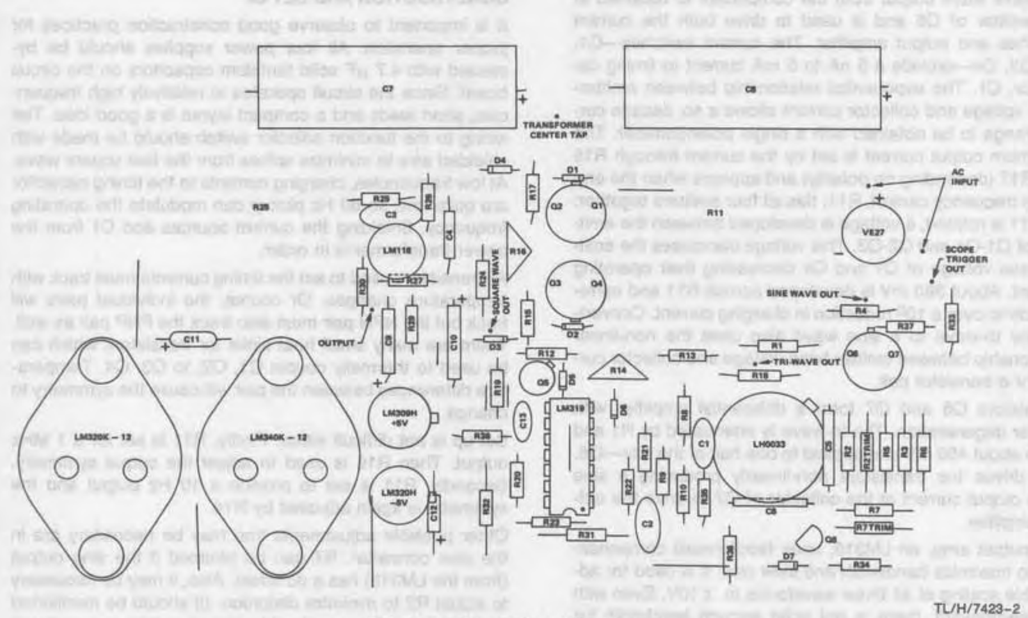
## CONSTRUCTION AND SET UP

It is important to observe good construction practices for proper operation. All four power supplies should be bypassed with 4.7 $\mu$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%.)

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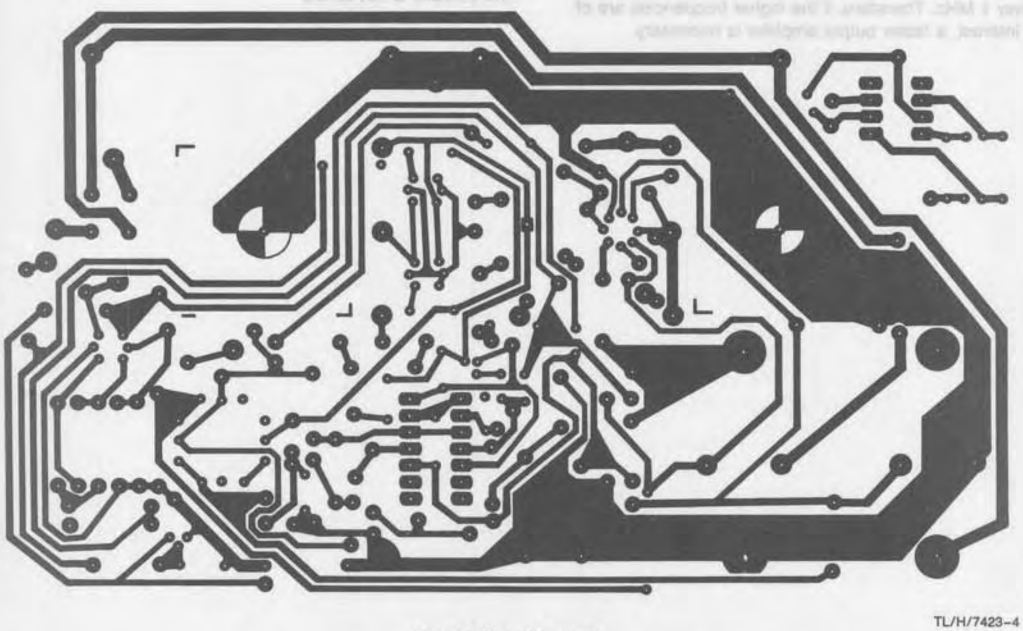
**Component Location, Top View**



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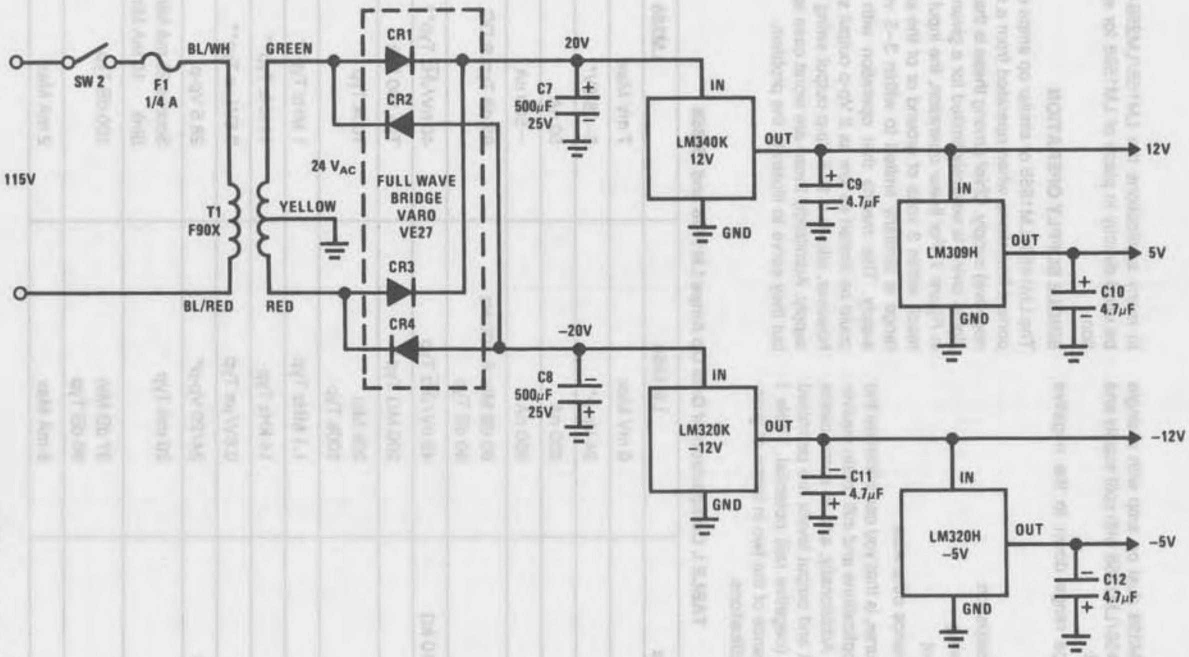
**Circuit Board Layout**
**(This PC layout must be enlarged approximately 120% in order to be usable.)**

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Power Supply Section Schematic