1.3V IC Flasher, Oscillator, Trigger or Alarm

National Semiconductor
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INTRODUCTION

Most linear integrated circuits are designed to operate with power supplies of 4.5 to 40V. Practically no battery/portable equipment is provided with indicator lights due to unacceptable power drain. Even LEDs (solid state lamps) won't light from a 1.5V battery, and drain the common 9V radio battery in a few hours.

The LM3909 changes all this. Obtaining long life from a single 1.5V cell, it opens a whole new area of applications for linear integrated circuits. Sufficient voltage for flashing a light emitting diode is generated with cell voltage down to 1.1V. In such low duty cycle applications batteries will last for months to years of continuous operation. Such flasher circuits then become practical for marking location of flashlights, emergency equipment, and boat mooring floats in the dark.

The LM3909 is simple in design, easy to use, and includes extra resistors to minimize external circuitry and the size of the completed flasher or oscillator.

CIRCUIT OPERATION

The circuit below in *Figure A* is the LM3909 connected as the simplest type of oscillator. Ignoring the capacitor for a moment, and assuming 1.5V on pin 5, current will flow in the 3k and 6k timing resistors through the emitter of Q_1. This current will be amplified by about 3 by Q_2 and passed to the base of Q_3. Q_3 will then conduct, pulling down on the base of Q_4 and hence the base of Q_1. This is a negative feedback since it will reduce timing resistor current and current to the power transistor's base until a balance is reached. This will occur with the collector of Q_3 at about 0.5V, the base of Q_4 at about 1V, and a very small voltage from pin 8 to ground. The difference between these two voltages is the base-emitter drop of Q_1 and 2/3 the base-emitter drop of Q_4 as set by the high resistance divider from its base to emitter.

Note that negative feedback *voltage* is attenuated by at least 2 due to the divider of two 400Ω resistors. Now considering the capacitor, its positive feedback is initially unity. Therefore the DC bias condition and the temporary excess positive feedback conditions are met and the circuit must oscillate.

The waveform at pin 8 of the above oscillator is shown below. The waveform at pin 2, the power transistor collector, is almost a rectangle. It extends from a saturation voltage of 0.1V or less to within about 0.1V of the supply voltage. The "on" period of course coincides with the negative pulses at pin 8. Other circuit voltages can easily be inferred from the two waveforms in *Figure B*.

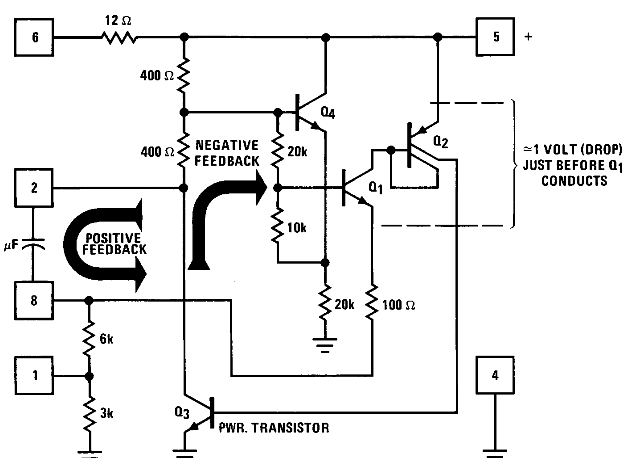

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FIGURE A

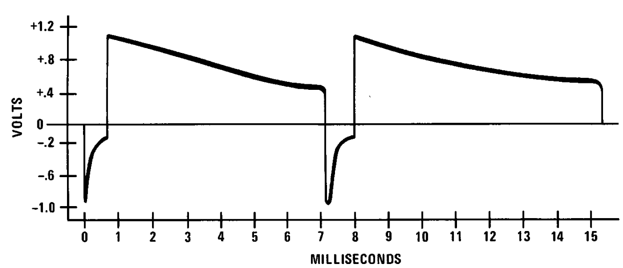

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FIGURE B

The simplicity of LED and incandescent pilot lamp flashers is illustrated below in *Figure 1.* In the LED flasher, the LM3909 uses the single capacitor for both timing and voltage boosting.

The LM3909, although designed as a LED flasher, is ideal for other applications such as high current, trigger pulse for SCRs and "Triacs." The frequency of oscillation adjusts from under 1 Hz to hundreds of kHz. Waveshape can be set from pulses a few μs wide to approximately a square wave. Thus the LM3909 can perform as a sound effects generator, an audible alarm, or audible continuity checker. Finally it can be a radio (detector/amplifier), low power one-way intercom, two-way telegraph set, or part of a "mini-strobe" light flashing up to 7 times per second.

Operating with only a 1.5V battery as a supply gives the LM3909 several rather unique characteristics. First, *no* known connection can cause immediate destruction of the IC. Its internal feedback loop insures self-starting of properly loaded oscillator circuits. Experimenters can safely explore the possibilities of the LM3909 as an AC amplifier, one-shot, latch circuit, resistance limit detector, multi-tone oscillator, heat detector, or high frequency oscillator.

With the accent on the practical, a brief circuit description will be given followed by circuits in the following application areas:

- Flasher & Indicator Applications
- Audio & Oscillator Applications
- Trigger & Other Applications

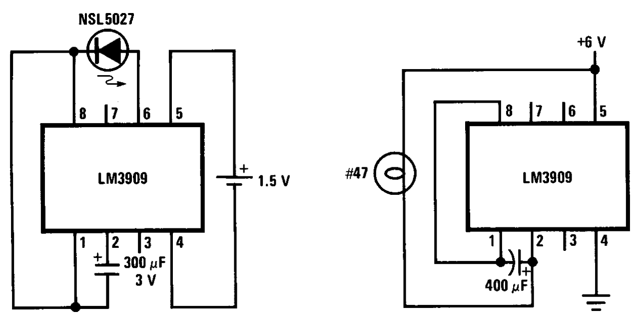
For those who want to modify or design their own circuits using the LM3909, application hints will be covered near the end of this note.

CIRCUIT DESCRIPTION

The circuit of *Figure 2* again shows the typical 1.5V LED flasher, but with the internal circuitry of the IC illustrated.

The flasher achieves minimum power usage in two ways. Operated as above, the LED receives current only about 1% of the time. The rest of the time, all transistors but Q_4 are off. The 20k resistor from Q_4's emitter to supply-common draws only about 50 μA. The 300 μF capacitor is charged through the two 400Ω resistors connected to pin 5 and through the 3k resistor connected to pin 1 of the circuit.

1.5V Flasher | Incandescent Bulb Flasher



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Note: Nominal Flash Rate: 1 Hz. | **Note:** Flash Rate: 1.5 Hz.

FIGURE 1. Two Simple Flashers

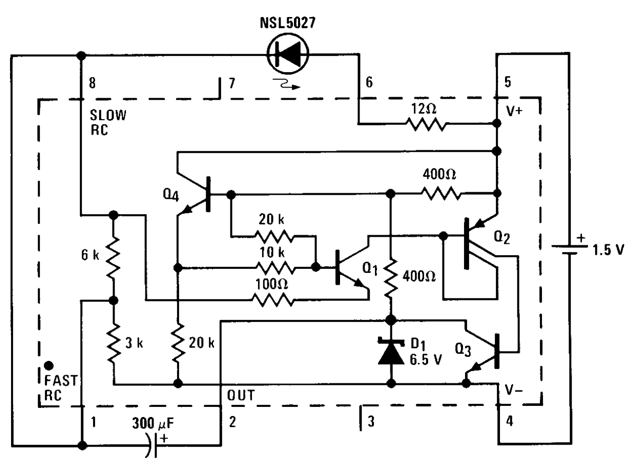

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FIGURE 2. Circuit Operation

Transistors Q_1 through Q_3 remain off until the capacitor becomes charged to about 1V. This voltage is determined by the junction drop of Q_4, its base-emitter voltage divider, and the junction drop of Q_1. When voltage at pin 1 becomes a volt more negative than that at pin 5 (supply positive terminal) Q_1 begins to conduct. This then turns on Q_2 and Q_3.

The LM3909 then supplies a pulse of high current to the LED. Current amplification of Q_2 and Q_3 is between 200 and 1000. Q_3 can handle over 100 mA and rapidly pulls pin 2 close to supply common (pin 4). Since the capacitor is charged, its other terminal at pin 1 goes *below* the supply common. The voltage at the LED is then higher than battery voltage, and the 12Ω resistor between pins 5 and 6 limits the LED current.

Many of the other oscillator circuits work in a similar fashion. If voltage boost is not needed (with or without current limiting) loads can be hooked between pins 2 and 6 or pins 2 and 5.

APPLICATIONS: FLASHER & INDICATOR

Differing uses and supply voltages will require adjustment of flashing rates. Often it is convenient to leave the capacitor the same value to minimize its size, or to fix the pulse energy to the LED. First, the internal RC resistors can be used to obtain 3k, 6k, or 9k by hooking to or shorting the appropriate pins. Further adjustment methods are shown in the two parts of *Figure 3* below.

In *Figure 3a*, it can be seen that the internal RC resistors are shunted by an external 1k between pins 8 and 4. This will give a little over 3 times the flashing rate of the typical 1.5V flasher of *Figure 1*.

The 3.9k resistor in *Figure 3b* connected from pin 1 to the 6V supply raises voltage at the bottom of the 6k RC resistor. Charging current through that resistor is greatly reduced, bringing flashing rate down to about that of the 1.5V circuit (1 Hz). As will be explained later, this biasing method also insures starting of oscillation even under unfavorable conditions.

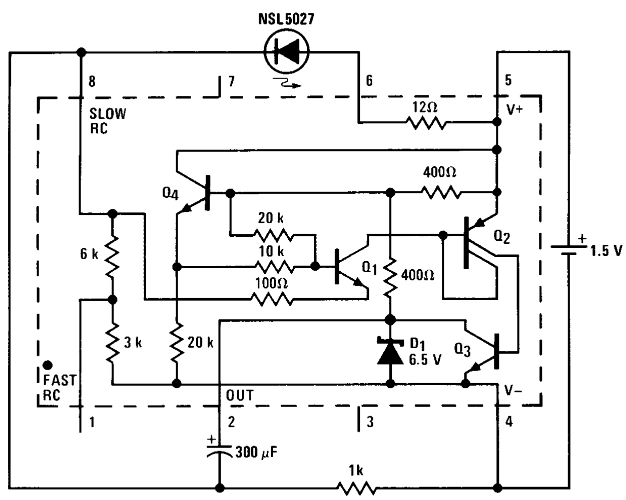

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FIGURE 3a. Fast Blinker

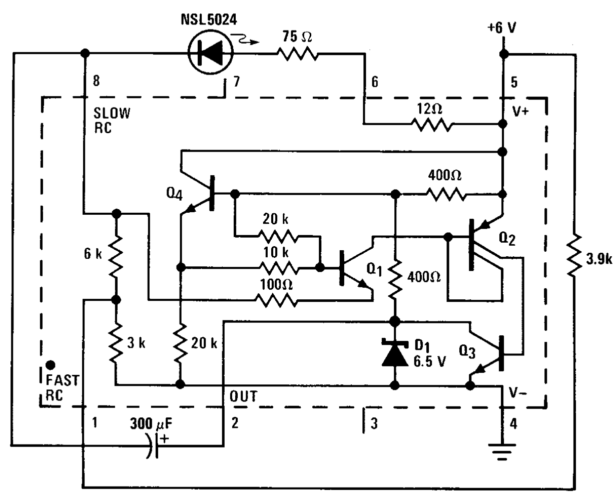

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FIGURE 3b. 6 Volt Flasher

Two precautions are taken for circuit reliability. The added 75Ω series resistor for the LED keeps current peaks within safe limits for the diode and IC. Also, in operation above a 3V supply, the electrolytic capacitor sees momentary voltage reversals. It should be rated for periodic reversals of 1.5V.

A continuously appearing indicator light can also be powered from a single 1.5V cell as shown in *Figure 4.* Duty cycle and frequency of the current pulses to the LED are increased until the average energy supplied provides sufficient light. At frequencies above 2 kHz, even the fastest movement of the light source or the observer's head will not produce significant flicker.

Since this indicator powering circuit uses the smallest capacitor that will reliably provide full output voltage, its operating frequency is well above the 2 kHz point. The indicator is not, however, intended as a long life system, since battery drain is about 12 mA.

High frequency operation requires addition of *two* external resistors, typically of the same value. One, of course, shunts the high internal timing resistors. If only this one were used, the capacitor charging current would have to pass through the two 400Ω resistors internally connected between pin 5 and the collector of Q3. Oscillation at a slower rate and lower duty cycle than desired would occur, and oscillation might cease altogether before the battery was fully discharged. The second 68Ω resistor shunting the two 400Ω resistors eliminates these problems.

The circuit in *Figure 5* is a relaxation type oscillator flashing 2 LEDs sequentially. With a 12 VDC supply, repetition rate is 2.5 Hz. C_2, the timing and storage capacitor, alternately charges through the upper LED and is discharged through the other by the IC's power transistor, Q_3.

If a red/green flasher is desired, the green LED should have its anode or plus lead toward pin 5 (like the lower LED). A shorter but higher voltage pulse is available in this position.

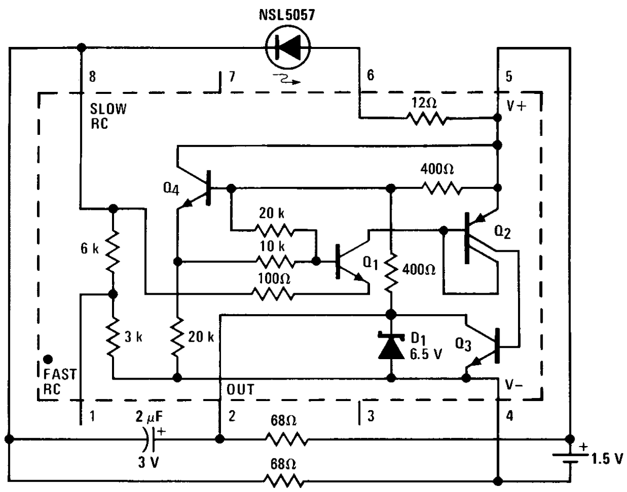

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FIGURE 4. "Continuous" 1.5V Indicator

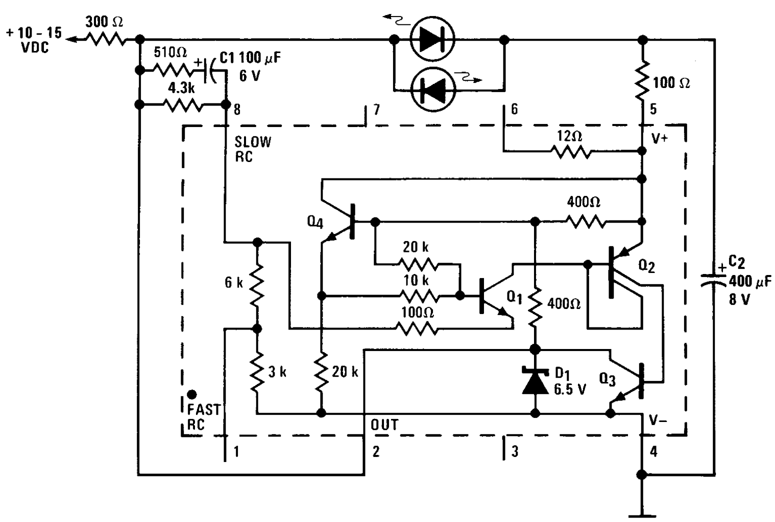

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FIGURE 5. Alternating Flasher

Indication or monitoring of a high voltage power supply at a remote location can be done much more safely than with neon lamps. If the dropping resistor (43k as in *Figure 6*) is located at the source end, all other voltages on the line, the IC, and the LED will be limited to less than 7V, above ground.

The timing capacitor is charged through the dropping resistor and the two 400Ω collector loads between pins 2 and 5 of the IC. When capacitor voltage reaches about 5V, there is enough voltage across the 1k resistor (to pin 8) to turn on Q_1, and hence trigger on the whole IC to discharge the capacitor through the LED.

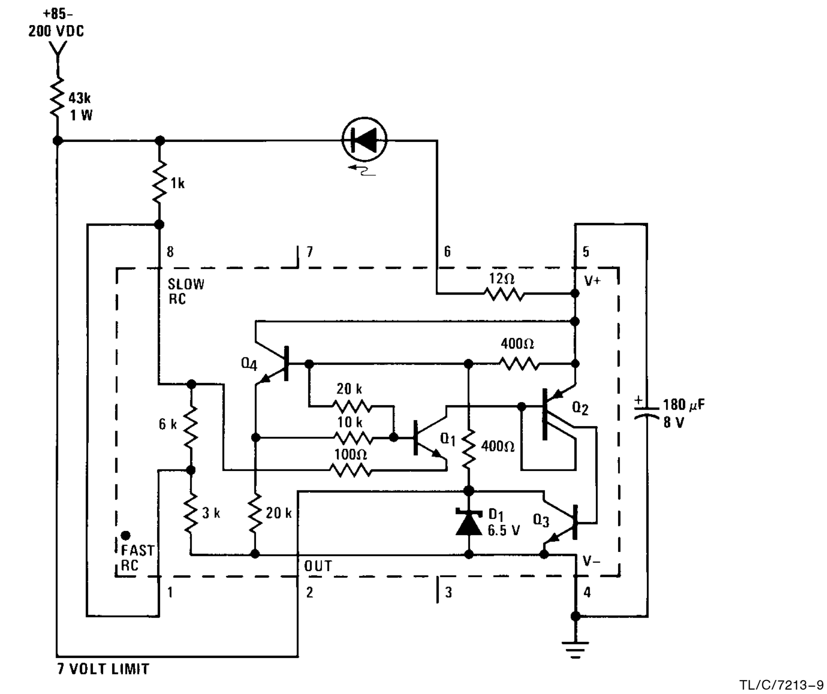

FIGURE 6. Safe, High Voltage Flasher

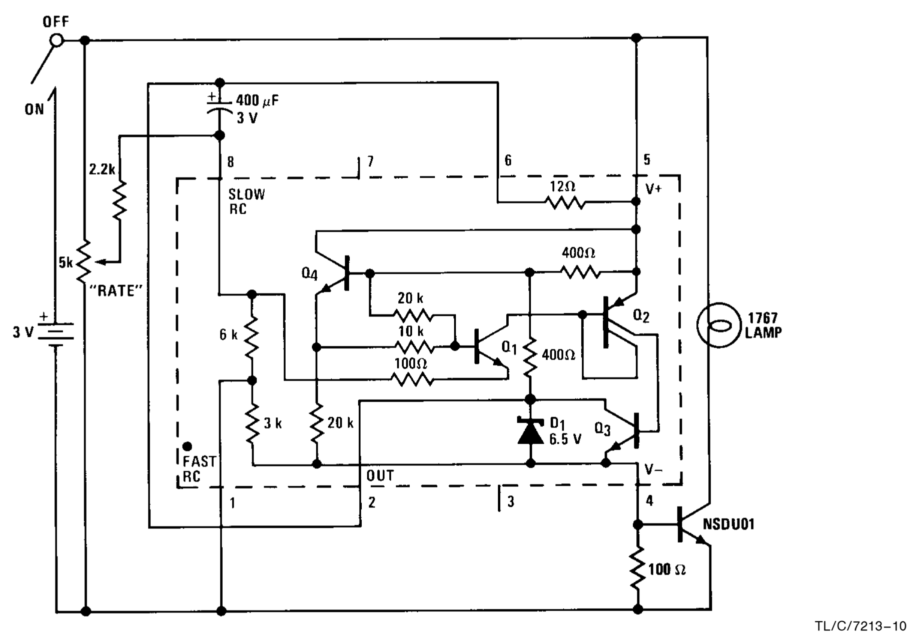

FIGURE 7. "Mini-Strobe" Variable Flasher

There are many other LED applications and variations of circuits. A chart outlining operation of the circuit of *Figure 6* at various voltages appears on the LM3909 data sheet. Also shown are circuits for adjusting the flash rate, flashing 4 LEDs in parallel, and details for building a blinking locator light into an ordinary flashlight.

Incandescent bulbs can also be flashed, as already illustrated in *Figure 1*. However, most such bulbs draw more than the 150 mA that the LM3909 can switch. The two following circuits therefore use an added power transistor rated at 1A or more. In each circuit, an NPN transistor is used, so the power transistor's base drive is obtained from the common or ground pin of the flasher IC.

The 3V "mini-strobe" of *Figure 7* may be used as a variable rate warning light or for advertising or special effects. The rate control is so wide range that it adjusts from no flashes at all to continuously on. Chosen for rapid response, the miniature 1767 lamp can be flashed several times a second.

A "mini-strobe" circuit was tested in a Lantern Flashlight with a large reflector. In a dark room, the flashes were almost fast enough to stop a person's motion. As a toy, the fast setting can mimic the strobes at rock concerts or the flicker of old-time movies.

Figure 8 below shows a higher power application such as would use an automotive storage battery for power. It provides about a 1 Hz flash rate and powers a lamp drawing a nominal 600 mA.

A particular advantage of this circuit is that it has only 2 external wires and thus may be hooked up in either of the two ways shown below in *Figure 9*. Further, no circuit failure can cause a battery drain greater than that of the bulb itself, continuously lit.

In the circuit of *Figure 8*, the 3300 μF capacitor performs a number of other functions. It makes the LM3909 immune to supply spikes, and provides the means of limiting the IC's supply voltage. Since the LM3909 can only operate with

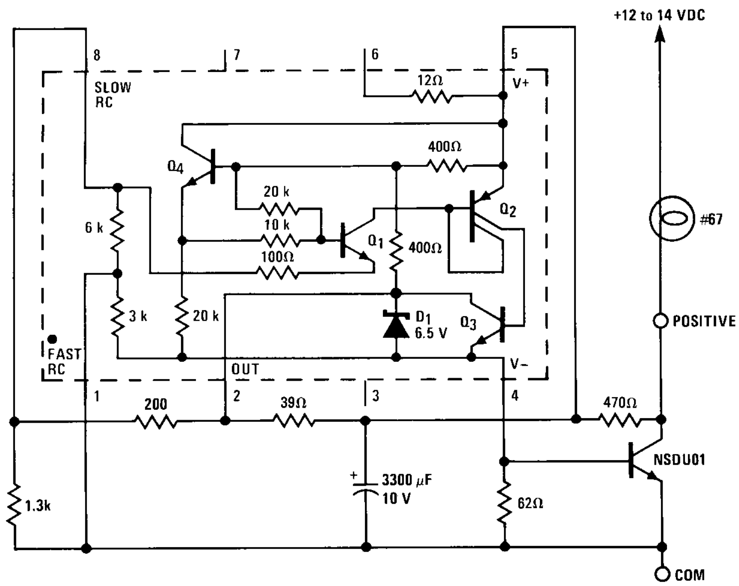

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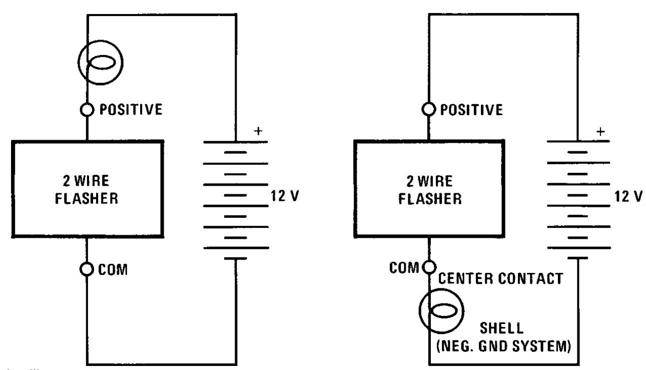
FIGURE 8. 12 Volt Flasher (2 Wire)



Note: If flasher case insulated, it will operate in positive or negative ground systems.

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FIGURE 9. 2 Wire Flasher Usage

7.5V or less on pin 5 (in this circuit) the 200Ω/1.3k divider attached to pin 8 of the IC causes it to turn fully on at 7V or less on pin 5. Then the LM3909 discharges the timing capacitor (its own supply voltage) to 4V or less, whereupon it turns off. The capacitor discharge current comes out of pin 4 of the IC, turning on the NSD U01 transistor. It is the large size of the timing capacitor that allows it to *store* all the needed energy for turning on the power transistor. This in turn permits the whole flasher circuit to operate as a 2 wire device.

Many other flasher possibilities exist. LED flash rate can be varied from 0 to 20 Hz, or a number of LEDs may be flashed in parallel. With a 3V supply, yellow and green LEDs may be flashed. A 6V incandescent "emergency lantern" can be made and its PR-13 bulb may be made to give continuous light or flash by switch selection. This is a more reliable, longer lived system than a lantern with a second thermal flasher bulb. The NSL4944 Current Regulated LED makes possible flashing many LEDs in parallel or with high voltages without series resistors.

APPLICATIONS: Audio & Oscillator

Very economical continuity checkers, tone generators, and alarms may be made from the LM3909. No matching transformer is needed because the 150 mA capability of the LM3909 output can drive many standard permanent magnet (transistor radio) loudspeakers directly. The 1.5V battery used in most applications is both lower in cost and longer lasting than the conventional 9V battery.

In the continuity checker of *Figure 10*, a short, up to about 100Ω, across the test probes provides enough power for audible oscillation. By probing 2 values in quick succession, small differences such as between a short and 5Ω can be detected by differences in tone.

A novel use of this circuit is found in setting the timing of certain types of motorcyles. This is due to the difference in tone that can be heard from the tester depending whether there is a short or not across the low resistance primary of the 'cycle's ignition coil. In other words, the difference between a 1Ω resistor and a 1Ω inductor can be heard. Quick checks for shorts and opens in transformers and motors can therefore be made.

Darkrooms, laundry rooms, laboratories, and cellar workshops can often suffer damage from spills or water seepage ruining lumber, chemicals, fertilizer, bags of dry concrete, etc. The circuit of *Figure 11* is safe on potentially damp floors since there is no connection to the power line. Further, its standby battery drain of 100 μA yields a battery life close to (or, according to some experiments, exceeding) shelf life.

Without moisture, multivibrator transistor Q_a is completely off, and its collector load (6.2k) provides enough current to hold pin 8 of the LM3909 above 0.75V where it cannot oscillate. When the sense electrodes pass about 0.25 μA, due to moisture, Q_a starts turning on, and since Q_b is already partially biased on, positive feedback now occurs. Q_a and Q_b are now an astable multivibrator which starts at about 1 Hz and oscillates faster as more leakage passes across the sense electrodes.

This "multi" then acts as both an amplifier and a modulator. The pulse waveform at the collector of Q_a varies the timing current through the 3.9k resistor to pin 8 of the LM3909 resulting in a distinctively modulated tone output.

The sensor should be part of the base of the box the alarm circuitry is packaged in. It consists of two electrodes six or eight inches long spaced about ⅛ inch apart. Two strips of stainless steel on insulators, or the appropriate zig-zag path cut in the copper cladding of a circuit board will work well. The bare circuit board between the copper sensing areas should be coated with warm wax so that moisture on the floor, *not* that absorbed by the board, will be detected. The circuit and sensor can be tested by just touching a damp finger to the electrode gap.

Minimum cost, simplicity, and very low power drain are the aims of the Morse Code set of *Figure 12.* One oscillator simultaneously drives speakers at both sending and receiv-

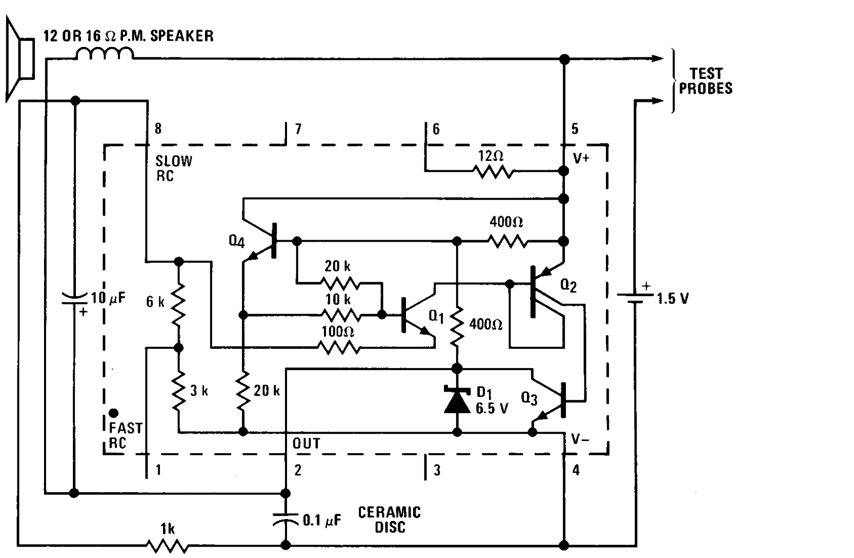

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FIGURE 10. "Buzz Box" Continuity and Coil Checker

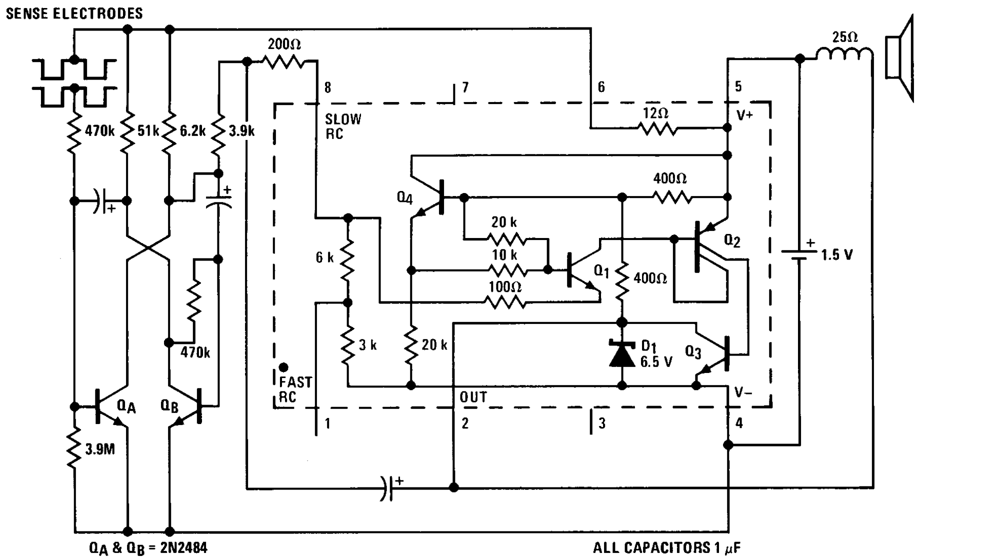

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FIGURE 11. Water Seepage Alarm

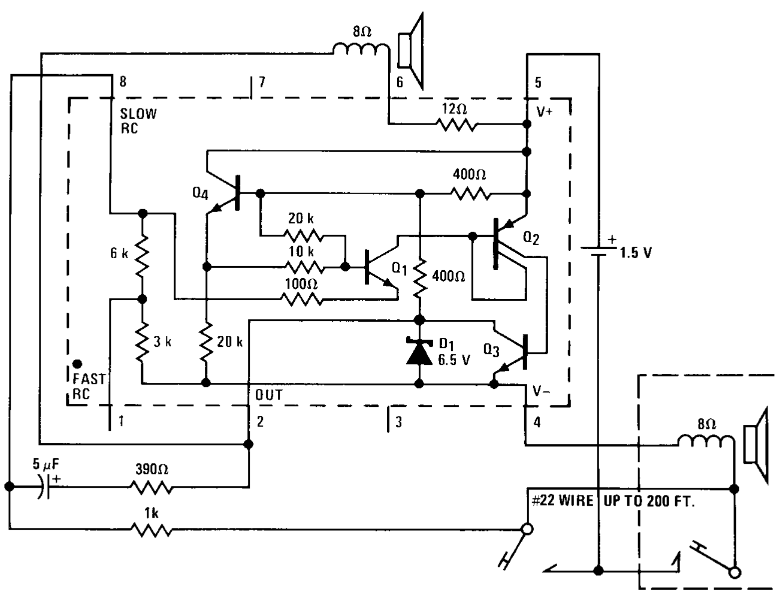

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FIGURE 12. Morse Code Set

ing ends. Calculations and actual use tests indicate life of a single alkaline penlight cell to be 3 months to over a year depending on usage. "Buzzer" type sets use two or more batteries with much shorter life.

Commonly available, low cost 8Ω speakers are effectively in series to better match LM3909 characteristics. The three wire system and parallel telegraph keys allow beginners and children to use the set without having to understand use of a "send-receive" switch.

The two resistors are added to obtain a suitable average power output and electrically force the oscillator toward the desired 50% duty cycle. Acoustically, both speakers are operated at resonance (about 400 Hz in the prototype) for maximum pleasing tone with minimum power drain. Each of the two speaker enclosures has holes added to augment this resonance. For each different type or brand of speaker and size of box, hole and capacitor sizes will have to be determined by experiment for the most stable resonant tone over the expected battery voltage variation.

Experiments with the above circuit led to development of circuit in *Figure 13.* It is optimized to oscillate at any *acoustic* load frequency of resonance! With just a speaker, oscillation occurs at the speaker cone "free-air" resonance. If the speaker is in an enclosure with a higher resonant frequency . . . this becomes the frequency at which the circuit oscillates.

An educational audio demonstration device, or simply an enjoyable toy, has been fabricated as follows. A roughly cubical box of about 64 in.^{3} was made with one end able to slide in and out like a piston. The box was stiffened with thin layers of pressed wood, etc. Minimum volume with the piston in was about 10 in.^{3}. Speaker, circuit, battery, and all were mounted on the sliding end with the speaker facing out through a 2¼ in. hole. A tube was provided (2½ in. long, 5⁄16 in. ID) to bleed air in and out as the piston was moved while not affecting resonant frequency.

"Slide tones" can be generated, or a tune can be played by properly positioning the piston part and working the push button. Position and direction of the piston are rather intuitive, so it is not difficult to play a reasonable semblance of a tune after a few tries.

The 12Ω resistor in series with pin 2 (output transistor Q_3's collector) and the speaker, decouples voltages generated by the resonating speaker system from the low impedance switching action of Q_3. The 100 μF feedback capacitor would normally set a low or even sub-audio oscillation frequency. Therefore, the major positive feedback voltage to pin 8 is the resonant motion *generated* voltage from the speaker voice coil. Therefore the LM3909 will continue to drive the speaker at the resonance with the highest combined amplitude and frequency.

It can be seen already that the LM3909, having direct speaker drive and resonance following capability, can do things that are a lot less practical with older timer and unijunction circuitry. Two final "sound effect" type of circuits are illustrated in *Figure 14.*

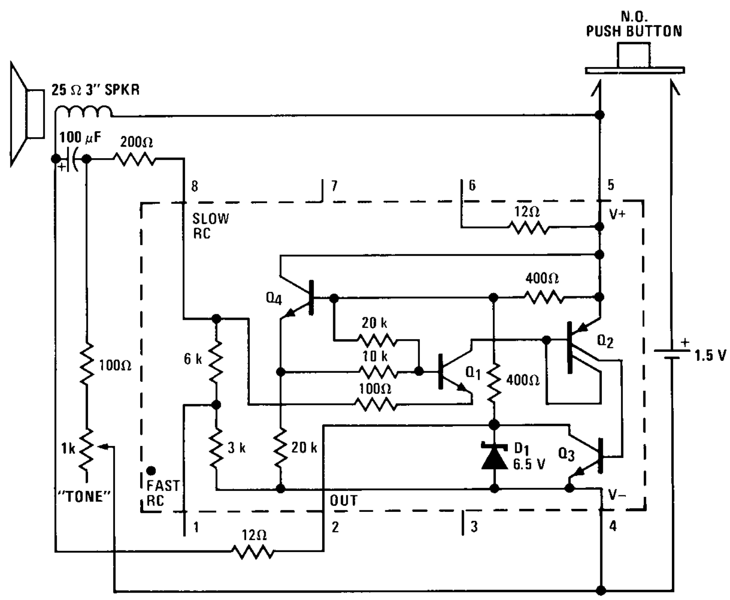

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FIGURE 13. Electronic "Trombone"

The siren of *Figure 14a* produces a rapidly rising wail upon pressing the button, and a slower "coasting down" upon release. If it is desirable to have the tone stop sometime after the button is released, an 18k resistor may be placed between pins 8 and 6 of the IC. The sound is then much like that of a motor driven siren.

In this circuit, the oscillation must not be influenced by acoustic resonances. The 1 μF capacitor and 200Ω resistor determine a pulse to the speaker that is wider than that for flashing LEDs, but much narrower than is used in the tuned systems of *Figures 12* and *13.* The repetition rate of speaker pulses is determined by the 2.7k resistor, and the charge on the 500 μF capacitor. Discharging this capacitor with the pushbutton increases current in the 2.7k resistor causing a rapid upshift in tone.

The "whooper" of *Figure 14b* sounds somewhat like the electronic sirens used on city police cars, ambulances, and airport "crash wagons." The rapid modulation makes the tone seem louder for the same amount of power input.

The tone generator is the same as in the previous siren. Instead of a pushbutton, a rapidly rising and falling modulating voltage is generated by a second LM3909 and its associated 400 μF capacitor. The 2N1304 transistor is used as a low voltage (germanium) diode. This transistor along with the large feedback resistor (5.1k to pin 8) forces the ramp generator LM3909 into an unusual mode of operation hav-

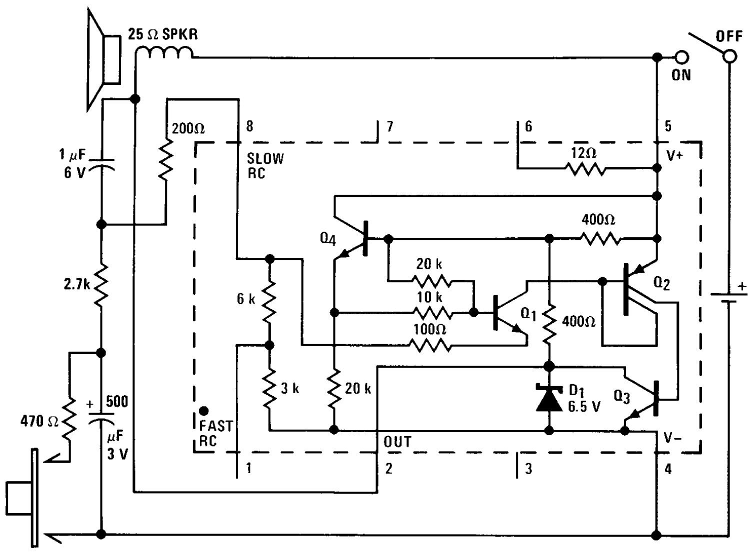

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FIGURE 14a. Fire Siren

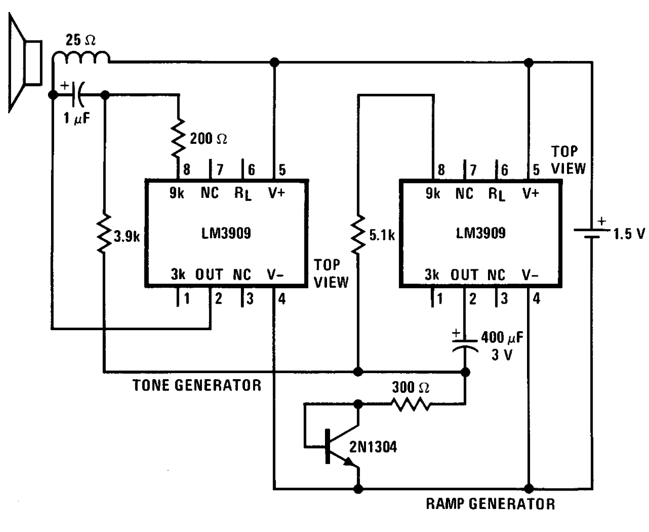

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FIGURE 14b. Whooper Siren

ing longer "on" periods than "off" periods. This raises the average tone of the tone generator and makes the modulations seem more even.

APPLICATIONS: Trigger & Other

With its high pulse current capability, the LM3909 is a good pulse-transformer driver. Further, it uses fewer parts and operates more successfully from low voltage supplies than do the equivalent unijunction circuits. The "Triac" trigger of *Figure 15* operates from a 5V logic supply and provides gate trigger pulses of up to 200 mA.

With no gate input, or a TTL logic high input, the LM3909 is biased off since pin 1 is tied to V+. With a logic low at the gate in, the IC provides 10 μs pulses at about a 7 kC rate. A TTL gate loaded only by this circuit is assumed since otherwise worst-case voltage swing may be insufficient. This trigger is not of the "Synchronized Zero Crossing" type since the first trigger pulse after gating on could occur at any time. However, the repetition rate is such that after the first cycle, a triac is triggered within 8V of zero with a resistive load and a 115 VAC line.

The standard Sprague PC mounting transformer provides a 2:1 current step-up, and suitable isolation between the low voltage circuitry and power lines up to 240 VAC. Resistor R_g, which includes transformer winding resistance, can be as little as 3 or 4Ω for high current triacs. Low current types may need excessive "holding" current with such low R_g, so it may be raised to as much as 100Ω with a sensitive gate triac.

Oscillation of the LM3909 will start when the DC bias at pin 8 is between 1.6 and 3.9V. In *Figure 15,* pin 8 is connected between the 10k input resistor and a 6k resistor to 5V. With 3.8V in, pin 8 is at 4.5V so there is no oscillation. With 1V, or less, in, pin 8 is at 3.5V or below and oscillation occurs. From this example, it can be seen that other input resistors or bias dividers can be calculated to gate the LM3909 triac trigger from other logic levels.

A useful electronic lab device is a precision square wave generator/calibrator. If the output is held at a few tenths percent of 1V, peak-to-peak, it is useful in calibrating oscilloscopes and adjusting 'scope probes. Many lower cost or battery-portable oscilloscopes do not have this feature built in. Also it is useful in checking gain and transient response of various amplifiers including "hi-fi" power amplifiers.

Battery powered equipment is free from both the inconvenience of a line cord, and from some of the noise and hum effects of equipment attached to the power line. Operation for over five hundred hours from a single flashlight "D" cell is the bonus provided by the circuit of *Figure 16.* The lowest reference voltage regulator available, the LM113, is used in conjunction with a current source, and the voltage boost characteristic of the LM3909.

Output is a clean rectangular wave which can be adjusted to exactly a 1V amplitude. A rectangular wave of approximately 1.5 ms "on" and 5.5 ms "off" was chosen for circuit simplicity and low battery drain. Waveform clipping is virtually flat due to complete turn-off of the current switch Q_2 and the typical "on" impedance of 0.2Ω provided by the LM113. The 0.01% temperature coefficient of the LM113 at room temperature allows negligible drift of the waveform amplitude under laboratory conditions. Loading by a 'scope probe will also be insignificant.

The circuit will work properly down to battery voltages of 1.2V. This is because the 100 μF electrolytic capacitor drives the emitter of Q_2 below the supply minus terminal. At a battery voltage of 1.2V, the collector of Q_2 can still swing more than 1.6V. Q_1 uses the "off" periods of the LM3909 to insure that the 100 μF capacitor is charged to almost the

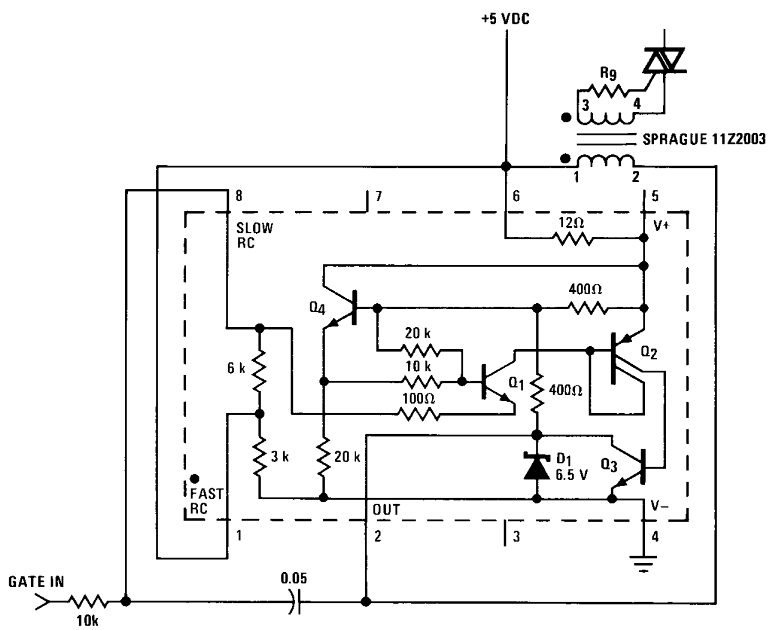

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FIGURE 15. Triac Trigger

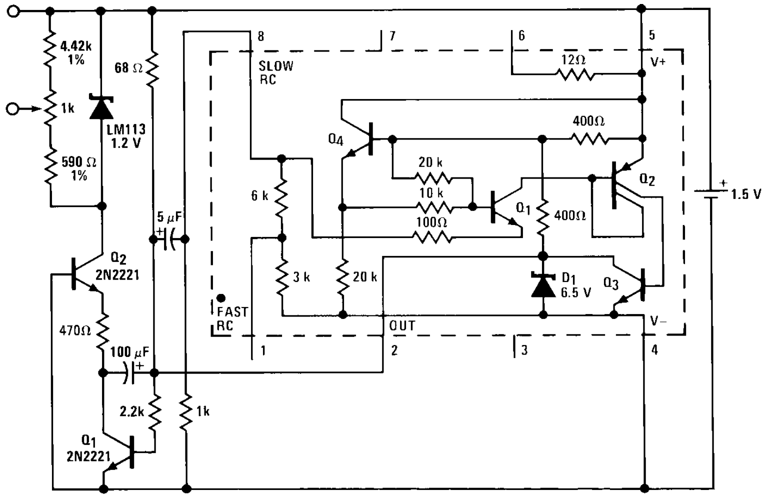


FIGURE 16. 'Scope Calibrator

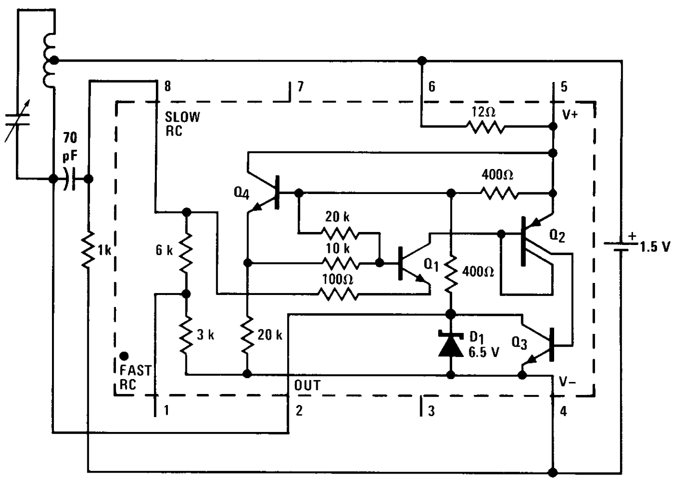


FIGURE 17. R.F. Oscillator

entire battery voltage. Thus when the LM3909 turns on and pin 2 drives almost to the minus supply voltage, the negative side of the capacitor is driven 0.9 to 1.2V below this terminal. Low battery voltage cannot lead to an undetected error in the 1V squarewave. This is because the waveform becomes distorted rather than just decreasing in amplitude as battery voltage becomes too low.

Taking advantage of the versatility and the indestructability of the LM3909 by a 1.5V battery, the IC can become an ideal teaching means, or experimental device for the young electronic hobbyist. As well as the circuits already presented, the LM3909 can be made to work as amplifier, radio, and even logic type circuits. The ideas of negative and positive feedback can be presented. The circuits presented in *Figures 17* through *21* are intended as illustrations or demonstrations of circuitry concepts such as would be used in an experimenter's kit. They are not meant to be used as parts of finished commercial products with specific performance specifications. In other words, working circuits have been breadboarded, but no measurements of performance such as frequency range and distortion have been attempted.

Both tuned circuits of *Figures 17* and *18* use standard AM radio ferrite antenna coils (loopsticks) with a tap 40% of the turns up from one end. The oscillator works up to 800 kHz or so, and the radio tunes the regular AM broadcast band. Both also use standard (360 pF) AM radio tuning capacitors.

The oscillator has the normal capacitive positive feedback used with LM3909 circuits, but with frequency determined by the tuned circuit loading the output circuit. Detailed operating descriptions of these experimenter's circuits will not be attempted in order to keep down the length of this note. Near the end, a discussion of the IC's general theory of operation will be given, which should help in understanding the individual circuits.

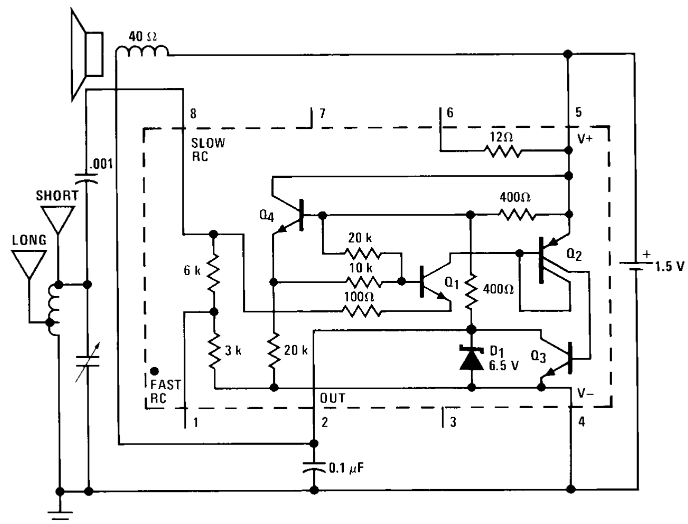
In the radio circuit of *Figure 18,* the LM3909 acts as a detector amplifier. It does not oscillate because there is no positive feedback path from pin 2 to pin 8. The tuning ability is only as good as simple "crystal set," but a local radio station can provide listenable volume with an efficient 6 inch loudspeaker. Extremely low power drain allows a month of continuous radio operation from a single "D" flashlight cell.

Antennae for the radio circuit can be short (10 to 20 feet) and connected directly to the end of the antenna coil as illustrated. Longer antennae (30 to 100 feet) work better if attached to the previously mentioned tap on the coil . . . also illustrated.

The following two circuits are examples of logic or computer type functions. They use 3V power supplies (2 cells) because the LM3909 was designed not to have any stable or "latching" states with a 1.5V supply.

Switches on both the above circuits are momentary types. In each case a small charge or impulse affects the circuit's state. The circuit of *Figure 19* switches to and *holds* its condition whenever the switch changes sides, even if contact is made only very briefly. The circuit of *Figure 20* delivers about a ½ second flash from the LED every time its pushbutton makes contact, whether briefly or for a much longer period of time. Such circuits are used with keyboards, limit switches, and other mechanical contacts that must feed data into electronic digital systems.

By again leaving out the positive feedback capacitor, the LM3909 can become a low power amplifier. This little audio amplifier can be used as a one-way intercom or for "listening in" on various situations. Operating current is only 12 to 15 mA. It can hear fairly faint sounds, and someone speaking directly into the microphone generates a full 1.4V peak-to-peak at the loudspeaker.



TL/C/7213–22

FIGURE 18. Radio

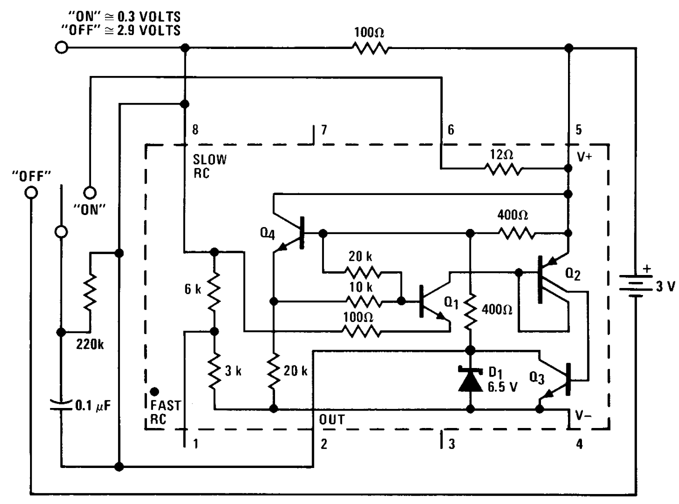


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FIGURE 19. Latch Circuit

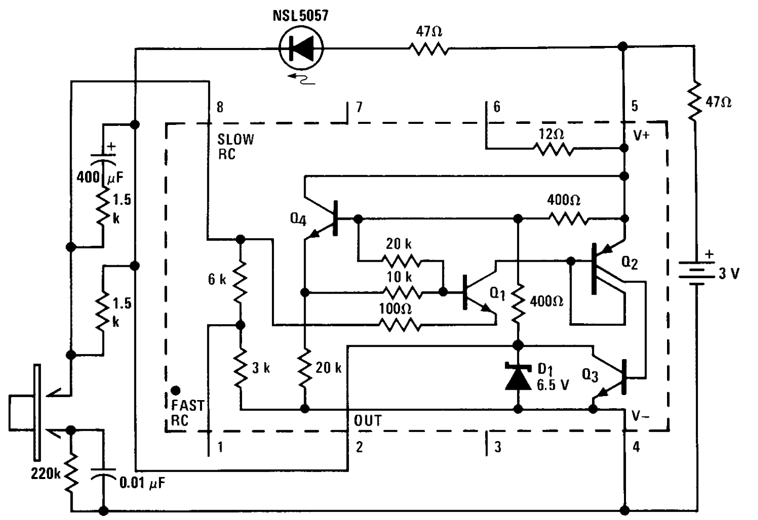

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FIGURE 20. Indicating One-Shot

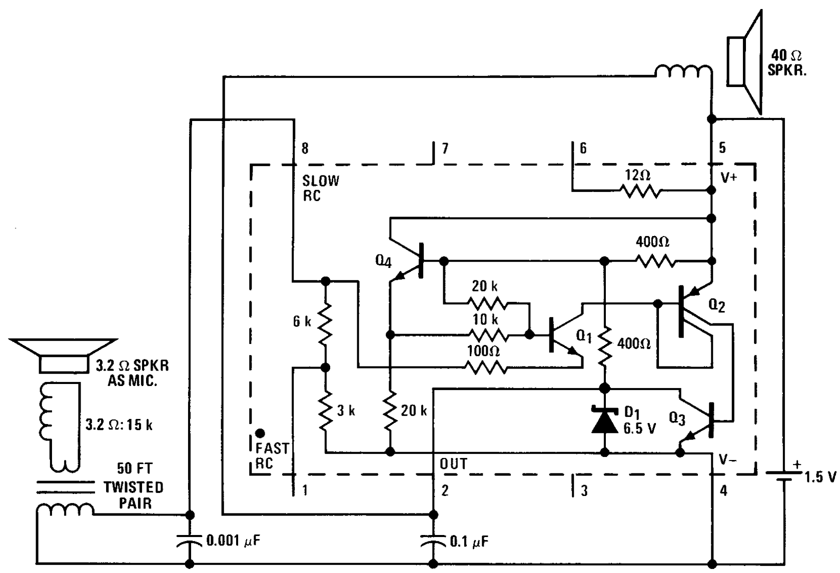

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FIGURE 21. Mini-Power Amplifier

APPLICATION HINTS

With 1.5V supplies, certain problems can occur to stop oscillation or flashing. Due to the way gain is achieved and the type of feedback, too heavy a load may stop an LM3909 from oscillating. 20Ω of pure resistive *load* will sometimes do it. Strangely enough, lamp filaments, probably because of some inductance, don't seem to follow this rule. Also in flasher circuits, an LED with *leakage* or conductivity between 0.9 and 1.2V will stop the LM3909. Maybe 1% of LEDs will have this defect because they are not often tested for it.

Greater frequency stability was not one of the design aims of the LM3909. In LED flasher circuits it is better than might be expected because the negative temperature coefficient of the LED partially compensates the IC. We planned it this way. Simple oscillators, without the LED, are uncompensated for temperature. This is due to using 1 ⅔ of a silicon junction drop as the on-off trip point and the use of the integrated timing resistors with their positive temperature coefficient. Further, most capacitors of 1 μF or over, shown in the circuits, will usually be electrolytics for size reasons. These, however, are not particularly stable with temperature and their initial tolerances vary greatly with type of capacitor.

In most of the oscillator circuits, frequency is also proportional to battery voltage. This must be considered when starting with a completely unused cell at 1.54V or so and deciding what the "end-of-life" voltage is to be. This can be in the range of 1.1 to 0.9V, a drastic change. It helps to remember how bright flashlights are with a fresh set of batteries, and how dim they are when the batteries are finally changed.

Flashers and tone generators for alarms are not, however, demanding for stability. Flash rate changes of 50% or tone shifts of ½ an octave are not particularly annoying or even too noticeable.

One interesting point is that the low operating power of most of the circuits presented allows them to be powered by *solar cells* as well as regular batteries. In bright sunlight, 3 to 4 cells in series will be needed. In dimmer light, 4 to 6 cells will do the job. Current from cells way under an inch in area generally will be sufficient, but circuits drawing a high pulse current (such as SCR triggers) will need a surge storage capacitor across the solar cell array.

The LM3909 was designed to be inherently self-starting as an oscillator, and LED flasher circuits *are*, at any voltage, because the load is nonlinear. A load with sufficient self inductance will always self-start, although possibly at a higher than expected frequency. There is an exception for largely resistive loads on an oscillator operating with a supply larger than 2 or 2.5V. A stable state exists with Q_3 turned completely "on" and the timing resistors from pin 8 to the supply minus still drawing current. A reliable solution is to bias pin 8 (for instance with a resistor to V+) so that its DC voltage is one half V less than half the supply voltage.

The duty cycle of the basic LED flasher is inherently low since the timing capacitor is also driving the very low LED "on" impedance. For other oscillators the "on" duty cycle can be stretched by adding resistance in series with the timing capacitor. Additionally, nonlinear resistance can be used as timing resistance. (See *Figure 14b*)

CONCLUSION

Applications covered in this note range in use from toys to the laboratory, and in frequency from DC to RF. The LM3909 can be used to amuse, teach, or even upon occasion to save a life. As a practical cost consideration the LM3909 IC can often replace a circuit having a number of transistors, associated parts, and high assembly cost.

Further, the LM3909 demonstrates the practicality of very low voltage electronic circuits. They can work at high efficiencies if ingenuity is used to design around transistor junction drops. In such circuits stresses on parts are so low that extremely long life can be predicted. Often transistors, capacitors, etc. that would be rejects at higher voltages can be used. Voltage dividers, protective diodes, etc. often needed at higher voltages can be left out of designs. Power drains are so low that circuits can be made that will last months to years on a single cell.

A single cell is more reliable and has a higher energy density then multiple cells. This is due to lack of cell interconnections and insulation as well as elimination of packaging to hold multiple cells in place.

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