

Austin-Healey Sprite Electronic Tachometer Conversion

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Introduction

My Austin-Healey “bugeye” Sprite has a mechanical tachometer. It has given me a certain amount of trouble, primarily from the mechanical parts jamming and breaking the drive gear. Drive gears, while available, are expensive, and the mechanical parts of the tachometer are delicate and easy to damage. Once repaired, the tachometer usually must be recalibrated, and this requires, in turn, some kind of secondary tachometer. It’s a nuisance. It makes an electronic tachometer, which would avoid all these problems, look attractive.

There are a number of ways to install an electronic tachometer. The most common are as follows:

Replace the mechanical tachometer with an electronic unit designed for later cars. This has a number of disadvantages:

- 1 The tachometer does not look like the original one.
- 2 The electronic tachometer uses small parts, such as tantalum capacitors, which tend to deteriorate over time. It may not work unless these parts are replaced.
- 3 The sensor wire loop, which goes through the tachometer, is in series with the ignition primary circuit. If the connector comes loose, your engine dies. Reliability engineers call this a *single point failure* and go to great efforts to identify and avoid such situations. These cars have enough reliability problems without building in unnecessary ones.

Replace the mechanical tachometer’s internals with the electronics of a modern tachometer. To do this, you need a modern tachometer whose range is equal to that of the mechanical tachometer, or has wide adjustability; whose pointer sweep angle is the same; and which fits into the space of the mechanical unit. I have never seen a modern tachometer that meets all these requirements.

Install a modern tachometer. Ugh! Absolutely the last option! Not only does this destroy the classic appearance, but you usually must make some kind of flange to mount your little two- or three-inch modern tachometer in the Sprite’s four-inch mounting hole.

My solution was to use the meter movement from a later, electronic tachometer and create new electronics to operate it. The movement could then be installed in the body of my old mechanical tachometer, or the “sacrificial” tachometer itself, with the new electronics, could be used. This turned out to be a fairly easy, fun electronics project. The rest of this document describes the background theory and the circuit that resulted.

How Electronic Tachometers Work

The operation of an electronic tachometer is fairly simple. Every time a spark plug fires, the ignition system triggers a voltage pulse at the output of the tachometer electronics. The tachometer’s electromechanical part, which is simply a kind of meter movement, responds to the average voltage of the series of pulses. It is possible to show that the average voltage of the pulse “train” is proportional to engine speed.

Figure 1 shows the pulse train that we need to generate. The pulses are *rectangular*; that is,

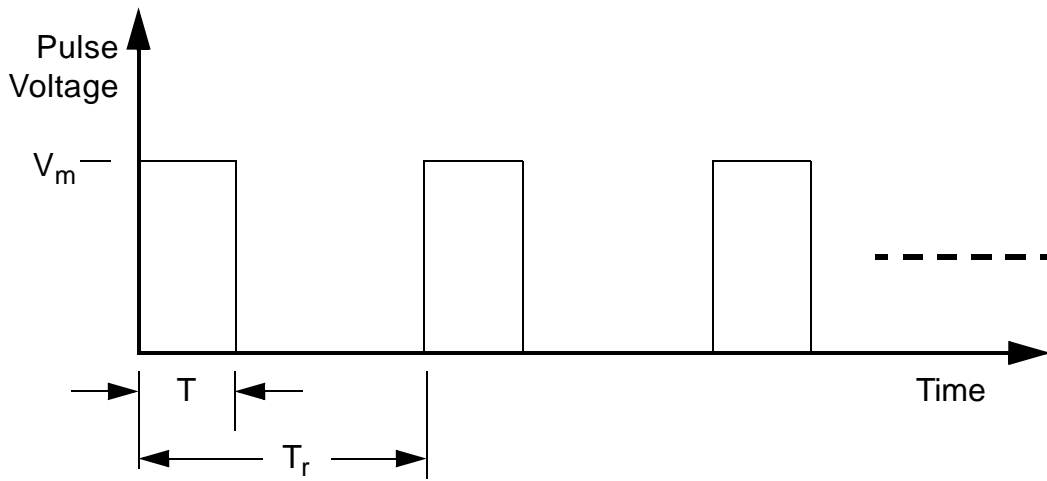


Figure 1 Pulse train generated by the electronics and applied to the tachometer’s electrical movement.

each pulse turns on suddenly and its voltage stays constant during the lifetime of the pulse¹. The *pulse length*, T , stays constant as engine speed varies. As speed increases, the time between pulses, T_r , decreases, so the *average voltage* of the pulse train, the voltage you would measure with a dc voltmeter, increases. Luckily, the average voltage turns out to be

1. Rectangular pulses actually are not essential. As long as the pulses are identical, and the shape does not vary with their rate, everything will be OK. Rectangular pulses are very easy to generate, however, so there is no real advantage to allowing nonrectangular pulses. Note that eq. (1) applies only to rectangular pulses.

proportional to engine speed. Since the pulses are triggered off the coil voltage, and the ignition system fires twice per revolution in a four-cylinder engine, the pulse rate (the number of pulses per minute) is twice the engine speed.

A little algebra gives the following equation for the average voltage, V_{av} , of the pulse train as a function of the pulse parameters:

$$V_{av} = \frac{CV_m TR}{120} \quad (1)$$

Where C is the number of cylinders of the car, V_m is the pulse voltage, T is the pulse length in seconds, and R is the engine speed in RPM. Clearly, there are some limits to these values. The pulses cannot run together, so, at the highest engine speed, T must be somewhat less than T_r . Additionally, to operate properly, the integrated circuit used to generate the pulses (an NE555 timer), needs some time between pulses to catch its electronic breath. Thus, T probably should be about half of T_r at the highest engine speed. Finally, the pulse voltage, V_m , is limited by the NE555 to a value a few tenths of a volt below the circuit's dc operating voltage.

The Circuit

To create this circuit, we need the electric meter movement from a sacrificial electronic tachometer. I ended up with two Smiths tachometers. The first is a three-inch unit that was used in a variety of cars: MGBs, Midgets, and Sprites after about 1968. The second is a four-inch unit that looks similar, but I'm not sure where it was used. These are readily available on eBay for \$25 to \$45. My plan was to replace the mechanical "guts" of the Sprite tachometer with the electromechanical parts of one of these tachometers and my new electronics. Of course, if your car uses a similar electric tachometer, you can simply modify your existing one. Figure 2 shows the four-inch tachometer removed from its enclosure.

An electronic tachometer has an electric movement, much like an ordinary, moving-coil analog meter. The smaller unit required 10 mA for the full 270-degree deflection of the indicator needle and had an internal resistance of 160 ohms; the larger required 23 mA and had a 73-ohm internal resistance. The voltage required for full deflection of the meter needle is the product of the full-scale current in amps and the resistance, giving 1.60V for the smaller and 1.68V for the larger. This is the minimum V_{av} , at top engine speed, that we must achieve. The electronic board, described below, works with either of these movements.

The longest pulse length allowable is based on a maximum speed of 6000 RPM. This is 12000 pulses per minute (remember, in a four-cylinder engine, the coil sparks twice per engine revolution), or 200 pulses per second. The pulse length, T in (1), must therefore be somewhat

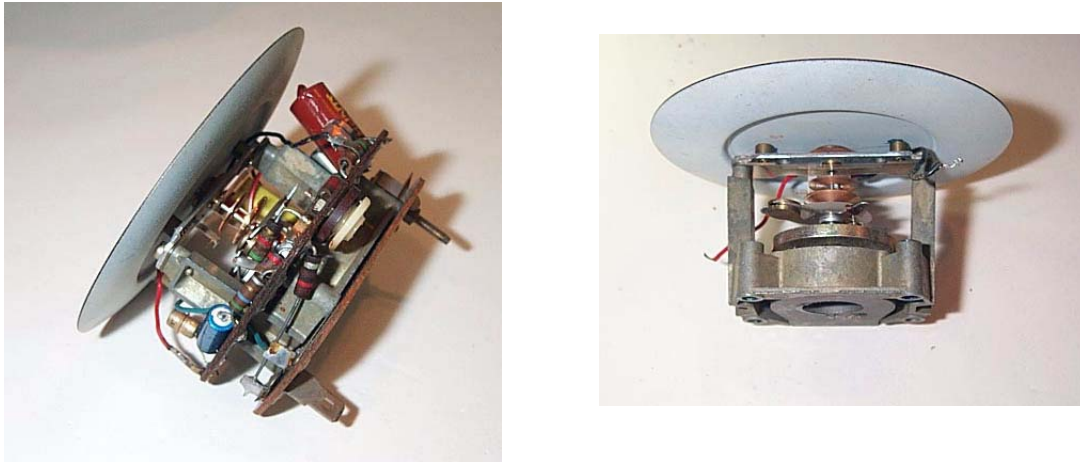


Figure 2. Four-inch electronic tachometer. The left figure shows the tachometer as it was received; the right figure shows it with the original electronics board removed. Only the wires connected to the meter movement are retained. Removing the electronics board is not, strictly, necessary, but it frees room in the housing to allow mounting of the new electronics board.

less than $1/200$ of a second, 5 mS. The pulse length was therefore set to 2.5 mS. Finally, the peak pulse voltage, V_m , was assumed to be 10V, giving $V_{av} = 5V$ at 6000 RPM. This is more than the 1.6V full scale of the meter, so it allows the use of a potentiometer in series with the meter for fine calibration of the tachometer. The ability to calibrate the tachometer in this way makes all the other parameters far less critical.

In order to make the coil voltage trigger the tachometer's pulse-generator properly, it is necessary to clean up the voltage waveform at the coil, so each time the ignition system fires, we get a smooth, clean pulse of voltage with a peak value of 3 to 4V. The measured waveform at the coil terminal connected to the distributor is shown in Figure 3. It consists of an initial pulse, an ac voltage having a frequency of about 10 KHz and an exponentially decaying envelope. The peak voltage, which occurs only about 25 microseconds after the points open, is 200V. This part of the waveform lasts approximately 0.8 to 1.0 mS; then, probably because the spark extinguishes, the frequency abruptly changes to about 2.5 KHz. At this point, the voltage increases slightly but again decays exponentially. Finally, when the points close, the voltage drops to zero.

To generate a trigger pulse for the tachometer electronics, it is necessary to decrease the

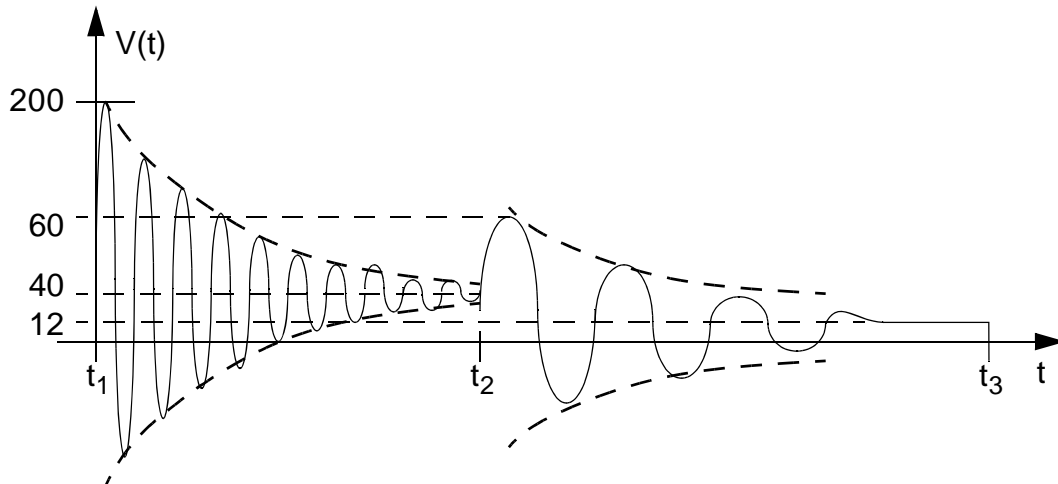


Figure 3. Voltage waveform at the coil terminal that connects to the points. This is the voltage that is sensed to trigger the pulse generator. At time t_1 , the points open, creating a voltage waveform of 10 KHz with a decay time constant of 0.4 mS. At t_2 , approximately 1 mS after t_1 , the spark extinguishes, causing a sudden change in the frequency and amplitude of the voltage; at this point it is approximately 2.5 KHz and 60V peak. At time t_3 , which depends on engine speed, the points close.

voltage, rectify it, and filter it a little. The “pulse-cleanup” circuit that does this is shown in Figure 4. It produces a clean, positive-going pulse approximately 4 volts in amplitude.

The pulse-generator circuit of the tachometer is shown in Figure 6 and a photograph is shown in Figure 7. It consists of a voltage regulator, a comparator, and the NE555 timer. The voltage regulator (type LM317) generates a dc voltage that remains constant as the temperature and battery voltage vary; this is essential for accuracy. The regulator should have at least 1.5V,

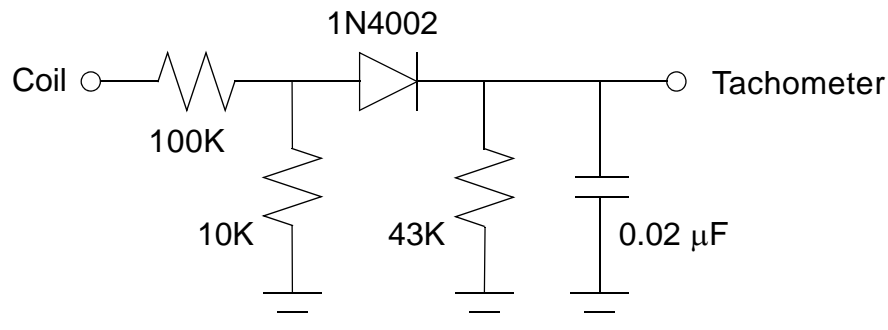


Figure 4. This circuit rectifies and filters the ac waveform shown in Figure 3, creating a clean pulse to trigger the tachometer. It is mounted close to the distributor, possibly some distance from the tachometer electronics. This circuit is correct for a points-capacitor ignition; for my Crane 700 CD ignition, it was necessary to change the 10K resistor to 20K. This is probably necessary for other CD ignitions as well.

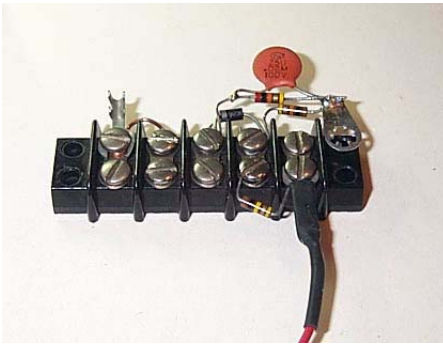


Figure 5. The pulse-cleanup circuit is mounted on a plastic barrier strip. This allows simple connections to the coil and tachometer. Extra terminals are connected to the switched power terminal of the fuse block and can be used for other additions to the car's electrical system as well as tachometer power.

preferably 2V, between its input and output. Therefore, the dc voltage was set to 8.6V instead of 10V assumed above. This setting allows a little more “headroom” for sagging of the battery voltage, which could drop as low as 11.0V when the car's electrical system is heavily loaded.

An LM311 comparator is used to detect the pulse from the pulse-cleanup circuit of Figures 4 and 5 and to trigger the NE555 timer. The positive terminal of the comparator is set to a little over 1V by the voltage divider, which consists of the 2.7K and 20K resistors. The pulse from the cleanup circuit is applied to the negative terminal; the 6V zener diode, the 43K resistor, and the 0.01 μ F capacitor protect the comparator from spikes that might be coupled into the cable from the ignition system. The 270K resistor provides approximately 0.1V of hysteresis, preventing instability in the comparator.

When no pulse is applied to the comparator, the negative terminal is at 0V so its output is high, nearly 9V. When a pulse is applied, the output goes low, almost to 0V, triggering the NE555 timer. The timer has some rather complicated rules for triggering; briefly, the trigger pulse must be considerably shorter than the timer's output pulse. For this reason, the comparator's output is capacitively coupled to the timer. This causes the negative-going voltage step at the comparator's output to create a short, negative spike at the timer's trigger terminal, easily satisfying the timing requirements.

The timer's pulse length, T in Figure 1, is determined by the 2.0K Ω resistor and 1.0 μ F capacitor connected to pins 6 and 7 (Figure 6). These values result in a 2.5 mS pulse each time the timer is triggered. The pulse train is applied to the meter movement through a 1K Ω , 10-

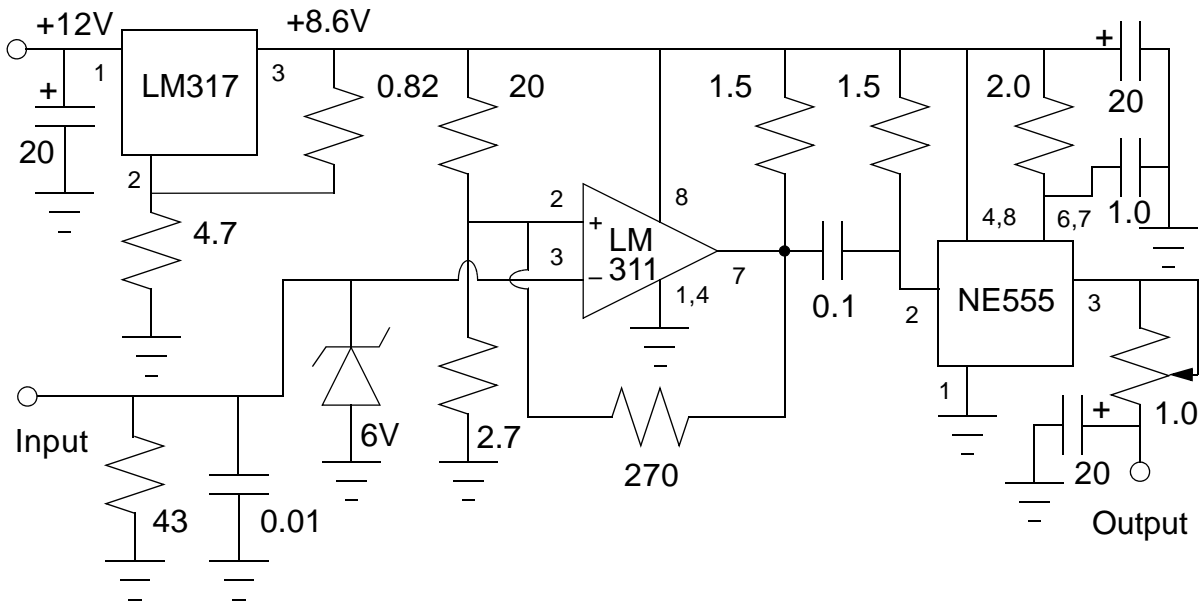


Figure 6. Circuit of the tachometer. Resistor values are in $K\Omega$, capacitors in μF . The *Input* terminal is connected to the *Tachometer* terminal in the pulse-cleanup circuit of Figure 4. The *Output* terminal goes to the meter movement of the sacrificial tachometer. The +12V connection should be made to a point that is switched by the ignition switch; the tachometer must be turned off when the ignition is turned off.

turn potentiometer, which is the tachometer's sole calibration adjustment. A 22 μF capacitor is connected in parallel with the output; it smooths the output voltage at low speeds, preventing a slight visible pulsation of the meter needle. It also prevents the meter's inductance from causing the NE555 to oscillate.

Figure 7 shows the prototype electronics board. Yes, it's messy but still is sturdy enough to be used as the final product. Perfectionists probably should make a printed circuit board for the electronics; this would be neater and perhaps a little smaller.

Calibration

The tachometer has only one adjustment, the 1K Ω potentiometer at the output of the NE555 timer. The potentiometer must be adjusted so that the tachometer shows the correct reading.

The simplest procedure is to connect the tachometer to the car, observe the reading on the existing tachometer, and adjust the potentiometer until the electronic tachometer agrees with the existing one. If the car does not have a working tachometer, life becomes somewhat more difficult. One option is to calibrate against an inexpensive optical tachometer. I have one that

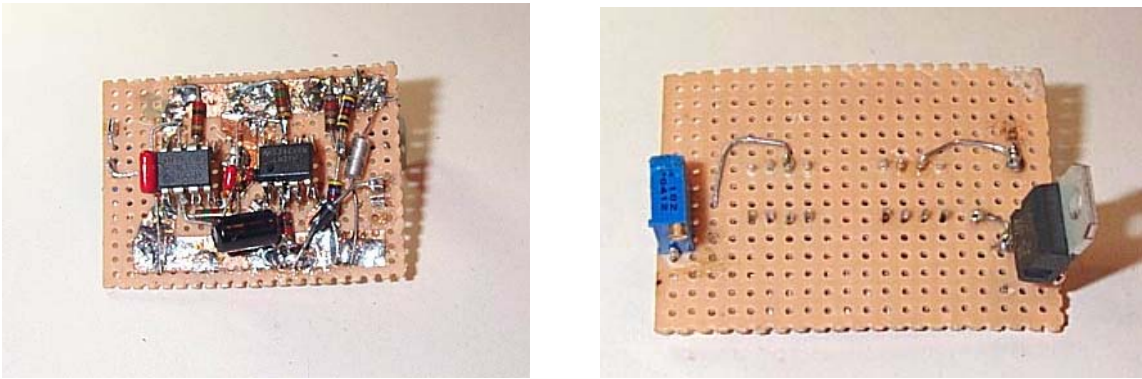


Figure 7. Front (left) and back (right) sides of the electronics board. The NE555 timer chip is on the left, and the LM311 comparator is on the right. Note the use of copper foil tape for the positive voltage and ground lines; this minimizes the chance of oscillation. The rear side shows only the voltage regulator and calibration adjustment potentiometer. These were mounted on the rear to minimize space, allowing the board to be mounted in the tachometer enclosure.

cost only \$25, and it's a very useful tool for many purposes.

Another possibility is to calibrate the tachometer from the ac output of a 12-volt transformer. The circuit is shown in Figure 8. Connect the output of this circuit to the input of the

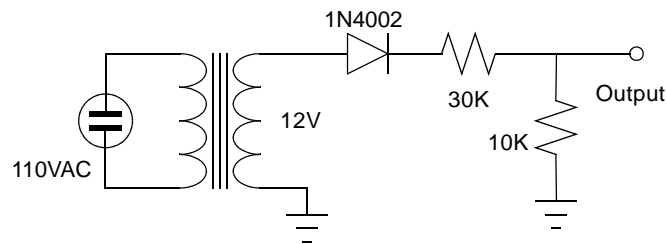


Figure 8. Calibration circuit for the tachometer. This circuit generates 4V pulses at a frequency of 60 Hz, which corresponds to precisely 1800 RPM with a four-cylinder engine.

tachometer electronics (i.e., do not include the pulse-cleanup circuit of Figure 4). The 60 Hz ac output of the transformer should cause a correctly calibrated unit, for a four-cylinder engine, to read 1800 RPM. Simply adjust the 1K Ω calibration potentiometer until the

tachometer indicates this value.

Putting It All Together

The cleanup circuit was built on a plastic barrier strip, which was mounted near the coil and the voltage regulator. This provided a convenient location for the components and screw connections for the wires to the tachometer.

The tachometer unit required a little modification. To provide a little more space for the electronic circuit board, I removed the old circuit board and sensing circuitry. The two connections to the meter movement were obvious; I simply connected these to the output of the new electronic circuit and its ground.

As the tachometer electronic circuit was built on a 1.5-inch by 2.5-inch piece of vectorboard, it was small enough to be mounted in the tachometer case once the original electronic parts were removed. In the end, I chose to use the movement from the three-inch tach and attached it to a tachometer face from a bug-eye Sprite mechanical tachometer. The board fit nicely, with no danger of components shorting or otherwise interfering with the meter movement. I also replaced the incandescent high-beam indicator with a light-emitting diode, which should be easier to see than the old incandescent bulb. I put a dab of black paint on the back of it so the light that illuminates the instrument at night doesn't shine through it, making it look like the high beams are on. In mounting all these parts, it is important to make sure that clearance is left for the illumination light and that mounting holes for the unit are clear of any interference in the can; for example, be sure you don't end up with a mounting hole right where the can's mounting stud happens to be. Figure 9 shows the board and meter movement mounted on the face plate.

If one were to use a different sacrificial tachometer, it would be necessary to measure the movement's internal resistance and the current required for full-scale deflection. If the product of these were greater than about 3V, the pulse length would have to be increased, per equation (1), by adjusting the value of the 2.0K Ω resistor connected to pins 6 and 7 of the timer. If the voltage were over 8V (which seems unlikely), the movement would not be usable. The output-current capability of the NE555, surprisingly, is not given on the data sheet, but power dissipation limits the full-scale current to no more than a few tens of milliamperes. If the meter required more than, say, 50 mA, it probably would not be usable.

The tachometer housing required a few more mounting holes, which I drilled as necessary. The pointer from the mechanical tachometer did not fit tightly on the pin from the 3-inch tachometer's movement, so I had to drill a hole in the pointer body and make a plastic bushing to adapt it. I then found that the pointer body stuck out farther than before, so the glass cover

interfered with it. It took a little finagling to get the whole thing together and working properly. Figure 10 shows the tachometer in the car and Figure 11 shows the pulse-cleanup circuit. The

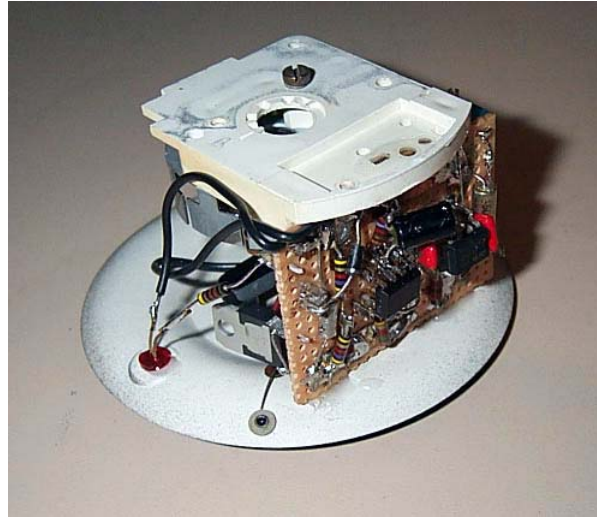


Figure 9 The movement from the three-inch tachometer was attached to the “bugeye” faceplate. Two new holes had to be drilled in the plate to accomplish this. The electronics board was attached with a couple dabs of epoxy, as was the LED for the high-beam indicator.



Figure 10. Tachometer installed in the sprite.

wiring from the cleanup circuit consists of the pulse output, +12V, and ground. The 12V supply is connected to the fuse block, the side that is controlled by the ignition switch. I used a set of connectors at the tachometer, so it could be removed easily for adjustment or repair. The high-beam indicator uses a set of spade terminals to connect to the wire at the existing



Figure 11. Pulse-cleanup circuit installed in the car. The twisted set of wires goes to the tachometer. Red and black are dc power and green is the triggering pulse.

high-beam light socket. I left the socket in place but, of course, unused, so the car could be converted back to a mechanical tachometer if desired. The amount of current required by the circuit is negligible.

Electronic Ignition

Before the project was completed, I installed a Crane XR700 electronic ignition in my Sprite. The coil voltage generated by this ignition is very different from the waveform in Figure 3, consisting of a short series of positive-going, half-sinusoidal pulses. To achieve a sufficiently high output voltage, it was necessary to change the 10K resistor in the pulse-cleanup circuit of Figure 5 to 20 K; no other modifications were necessary. The cleaned-up pulse in this case was about 2.6V, a little lower than previously, but still quite adequate to trigger the tachometer electronics.

Other electronic ignition circuits may work differently, so it is difficult to suggest modifications for them. Ideally, one should check the output of the pulse-cleanup circuit with

an oscilloscope and adjust the value of the 10K resistor until the output pulse is between about 2V and 5V. This should give good triggering of the tachometer circuit with decent noise immunity.

Some Caveats

The purpose of this document is to show how I designed and built the tachometer and to describe the underlying concepts. My goal is not to present a detailed, step-by-step electronics project. I have tried to minimize technical terminology and concepts, so anyone with modest experience in electronic experimentation should be able to duplicate what I've done. If you decide to undertake a project like this, and have minimal experience with this kind of work, it might not be a bad idea to have some help in undertaking it.

My Sprite has been converted to negative ground. **The circuit described in this document works only in a negative-ground car.** I haven't thought much about how this could be implemented in a positive-ground car, but it is clear that substantial modifications would be necessary.

Safety: Ignition voltages are high; not only the ~30,000V secondary voltage, which we all know about, but also the ignition coil's primary voltage. Figure 3 shows that the peak voltage on the coil's primary terminals reaches 200V. That's high enough to be dangerous. Respect it.