THE SMITHS INSTRUMENTS RVC 1410/00 AND RVC 1410/00AF TACHOMETERS

Rick Astley 2012

Introduction

In my books *MGB Electrical Systems* and *Classic British Car Electrical Systems* I addressed the Smiths RVC tachometers but was unable to describe the circuits in detail because no information regarding the Texas Instruments integrated circuit (IC) used in these instruments was available. Attempts to learn more about the IC using Texas Instruments contacts in both Dallas, TX and Bedford, UK, as well as trying to locate a knowledgeable veteran of Smiths Industries' Automotive Division have proven unsuccessful. However, even if the full circuit and function of the IC were known, in would probably be moot, since the device was evidently custom, specialized, no longer available and has no near equivalent.

Even if more detail were available, books have limited space and an author always has to weigh how appropriate each subject might be to an average readership and so cannot spend too many columns on material that is too esoteric. This document's purpose is to record what I have learned about these tachometers that might be of benefit to the small number of enthusiasts that may wish to try to repair or refurbish them. Unfortunately, my skills are limited to electrical ones, and I will make no attempt to address mechanical issues with these instruments; my own ham-fisted attempts to repair the instrument movements of some tachometers resulting in their demise. That is not to say that anyone refurbishing one of these instruments should not pay attention to the meter movement; rust and other metallic oxides are evident on some examples causing 'stiction' of the bearings and interfering with the free movement of the moving-coil over its magnetic former — between which items there is a very small air-gap. I have also seen some distortion of the moving-coil due, perhaps, to overheating resulting from the use of a too higher wattage halogen illumination lamp.

Although titled "RVC 1410/00 and RVC1410/00AF", using the marked references of the instruments used in MGBs, the same internal parts were used in a variety of different tachometers with different dial styling and/or included warning lamps and used in a number contemporary British and Swedish cars. These are believed to include, but are not limited to the: RVC 1414/00F, RVC 2010/00AF , RVC 2010/02F, RVC 2010/D0F, RVC 2414/01, RVC 2414/01F, RVC 2432/00F, RVC 2432/01F, RVC 2610/01, RVC 2612/00, RVC 2615/00F, RVC 6418/00F, RVC 6419/00, RVC 6419/00F, RVC 6811/00F.

Tachometer Basics

Before looking at the RVC tachometer circuits in detail, it's worth reviewing how a tachometer works.

In modern cars, say those from the mid-1980s onward, the tachometer takes its input from a speed-sensor that picks up the rotation speed of the crankshaft. It usually comprises a magnet or magnets that rotate in close proximity with a coil of wire. When a magnet passes the coil, its magnetic field crosses the coil wires and induces a voltage and current into them. Since each coil of wire is effectively in series with the next, the more turns of wire in the coil, the higher the voltage induced. The signal can be used to determine the speed of the engine and used by a variety of vehicle systems including the tachometer, cruise control, engine management computer and transmission management computer. A similar device, at the transmission output or at a wheel, can be used for vehicle speed measurement. The pulses from such a sensor are not regular because the faster the magnets pass the coil of wire, the higher the voltage induced. As a result, any system, including the tachometer that uses such a signal for speed determination, needs to in some way make the voltage pulses more regular.

At the other end of the scale, the earliest vehicle tachometers were mechanical devices cable driven from the camshaft or generator. Although the camshaft rotates at half engine speed, it was of course easy to calibrate the gauge to read actual crankshaft revolutions per minute. Jaguar later swapped out the cable drive for an alternating-current (ac) generator, which produces an output voltage proportional to the speed at which it is driven. The output is both reliable and repeatable, so a voltmeter, calibrated in RPM can be simply used as a tachometer gauge.

Most electrical tachometers, introduced in the early 1970s, register the pulses to or from the primary of the ignition coil. The earliest Smiths models, mostly prefixed with the type number RV1, actually monitored the current flowing to the coil. Every time the contact breaker points close, current flows through them to the coil primary. If those current pulses are detected, amplified and shaped to be reasonably uniform in magnitude and duration, they may be used measure the engine speed.

The later RVC instruments instead sampled the voltage at the coil primary. The voltage waveform here is far from regular, as illustrated in Figure 1, reflecting as they do the signal on the secondary of the coil that drives the spark plugs. The spark voltage may be between 5kV (1kV = 1,000 Volts) and 20kV. The wider the plug gap the higher the voltage required to produce a spark across it. Also the higher the cylinder pressure, the higher the voltage required. As ignition coils generally have a turns ratio (the ratio between the number of turns of wire on the secondary to that on the primary) of between 100 and 70:1, using these numbers the voltage at the primary might be between 50V (5,000 ÷ 100) and 286V (20,000 ÷ 70). Note that after the initial peak that fires the plug, the voltage takes a little while to settle.

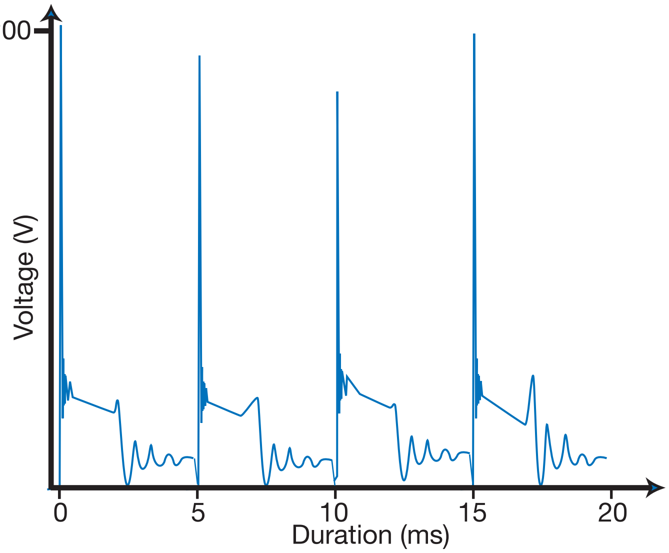


Fig 1. Typical coil primary signal.

Figure 1 shows 4-sparks taking a total of 20ms (1ms or millisecond = $^{1}/_{1000}$th of a second). If this were a 4-cylinder engine, it would take 2 engine revolutions to produce 4-sparks and so, in this illustration, a single revolution takes 10ms. That means that each second, the engine turns 100 times (1 ÷ (10 x $^{1}/_{1000}$)) or 6000 rpm (100 x 60), a very high engine speed. Under most operational conditions, the engine would be turning much more slowly, so some more space could be expected between each spark pulse represented in Figure 1.

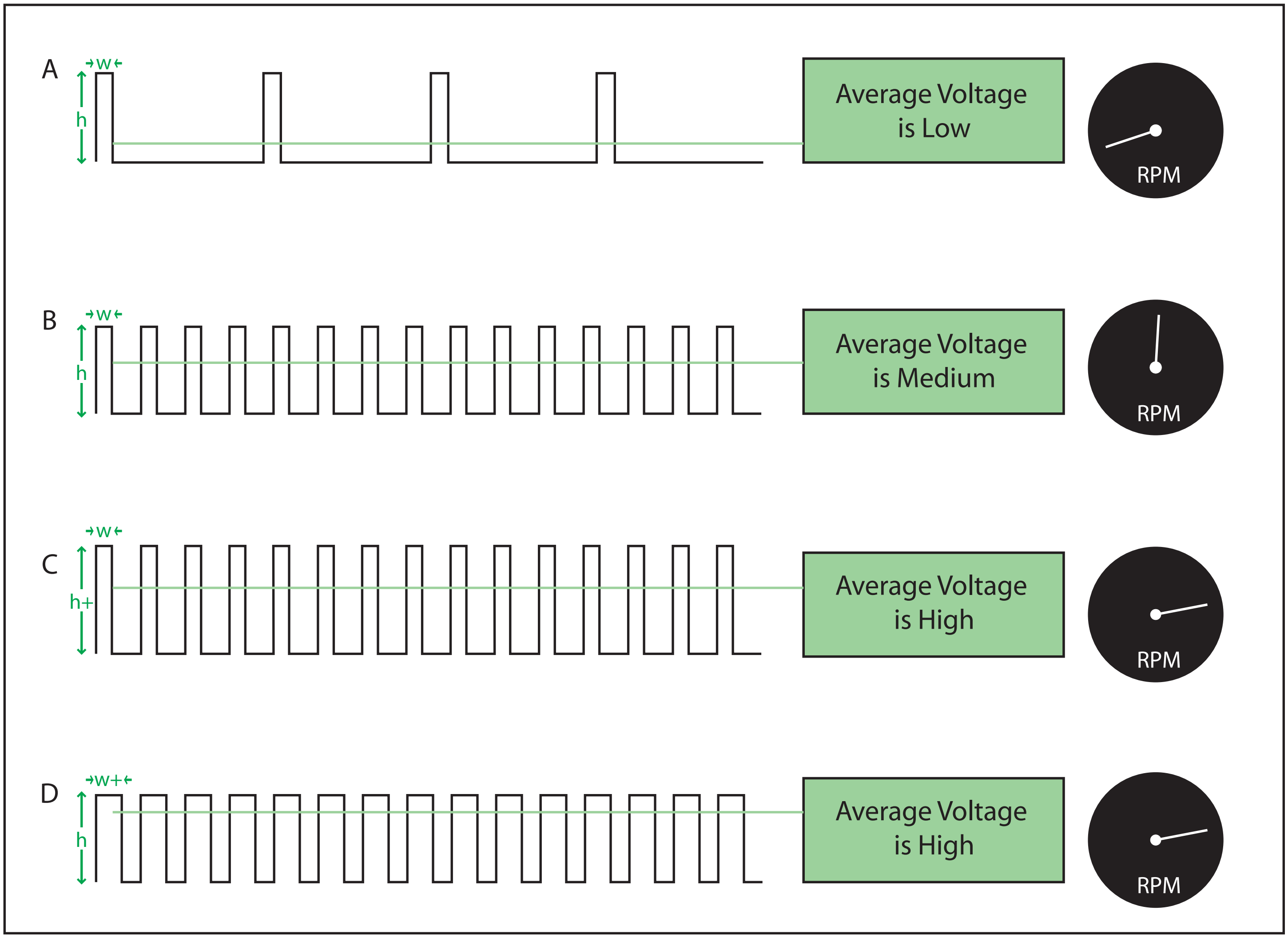


Fig. 2. Principle of Tachometer Operaration

In order to make sense of the ragged waveform input from the coil primary, the tachometer tries to turn it into a waveform that is much more uniform and regular. It usually does that by using the initial voltage spike shown in Figure 1 to trigger the start of a pulse generated by the electronics of the tachometer. Further, once that pulse is initiated, the electronic circuit is configured so that it ignores any further pulses until its self-generated pulse is completed.

Figure 2 illustrates how such regular pulses can be easily interpreted as a number of engine revolutions per minute (RPM).

Figure 2A shows how at low engine speeds the widely spaced, short and uniform pulses indicate a low value on the gauge, which is in effect a voltmeter. When the engine speed is increased, the pulses, which are still of the same magnitude and duration, come far more frequently, and as shown in Fig 2B, the average measured value is somewhat higher. An even higher rate of pulses will, of course, make the gauge register an even higher RPM reading. In order to provide some adjustment for the purposes of calibration, either the magnitude of the pulses (h+ in Figure 3C) or the duration (w+ in Figure 3D) can be changed.

Circuit Description

The circuits for the RVC 1410/00 and 1410/00AF are very similar, but the circuit boards are very different. The 1410/00 is very conventional, having a regular drilled printed circuit board (PCB) with through-hole discrete components while the 00AF has a ceramic PCB with a mix of discrete capacitors and an IC, but with thick-film printed resistors.

The heart of both is the Texas Instruments IC. Even the part number of this item is uncertain. As Figures 3 through 5 show, MIC 2/C is a consistent marking on the illustrated ICs as well as all others seen by the author, but may not necessarily be the correct designation. The number to the right side is probably a batch code and may be a year + week or year + manufacturing batch reference.

RVC 1410/00

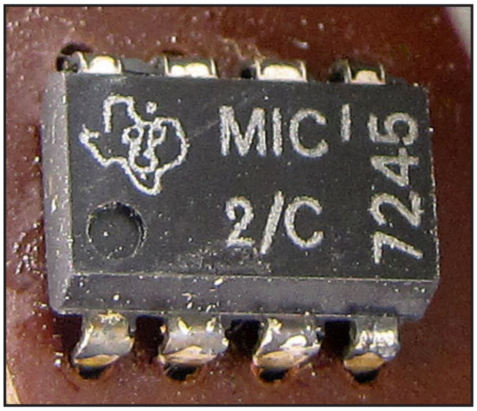


Fig. 3. MIC 2/C Example 1.

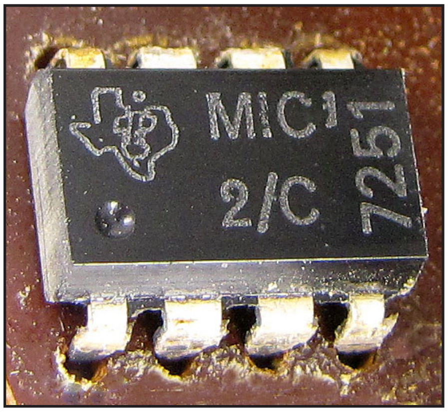


Fig. 4 MIC 2/C Example 2.

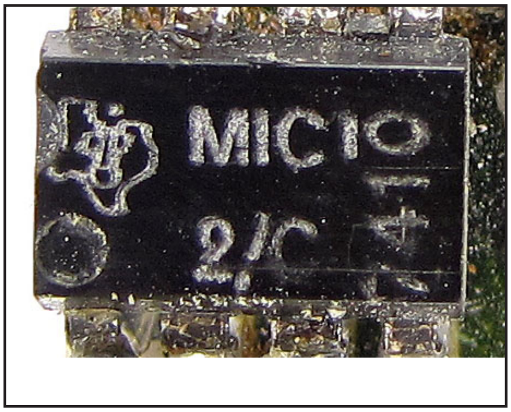
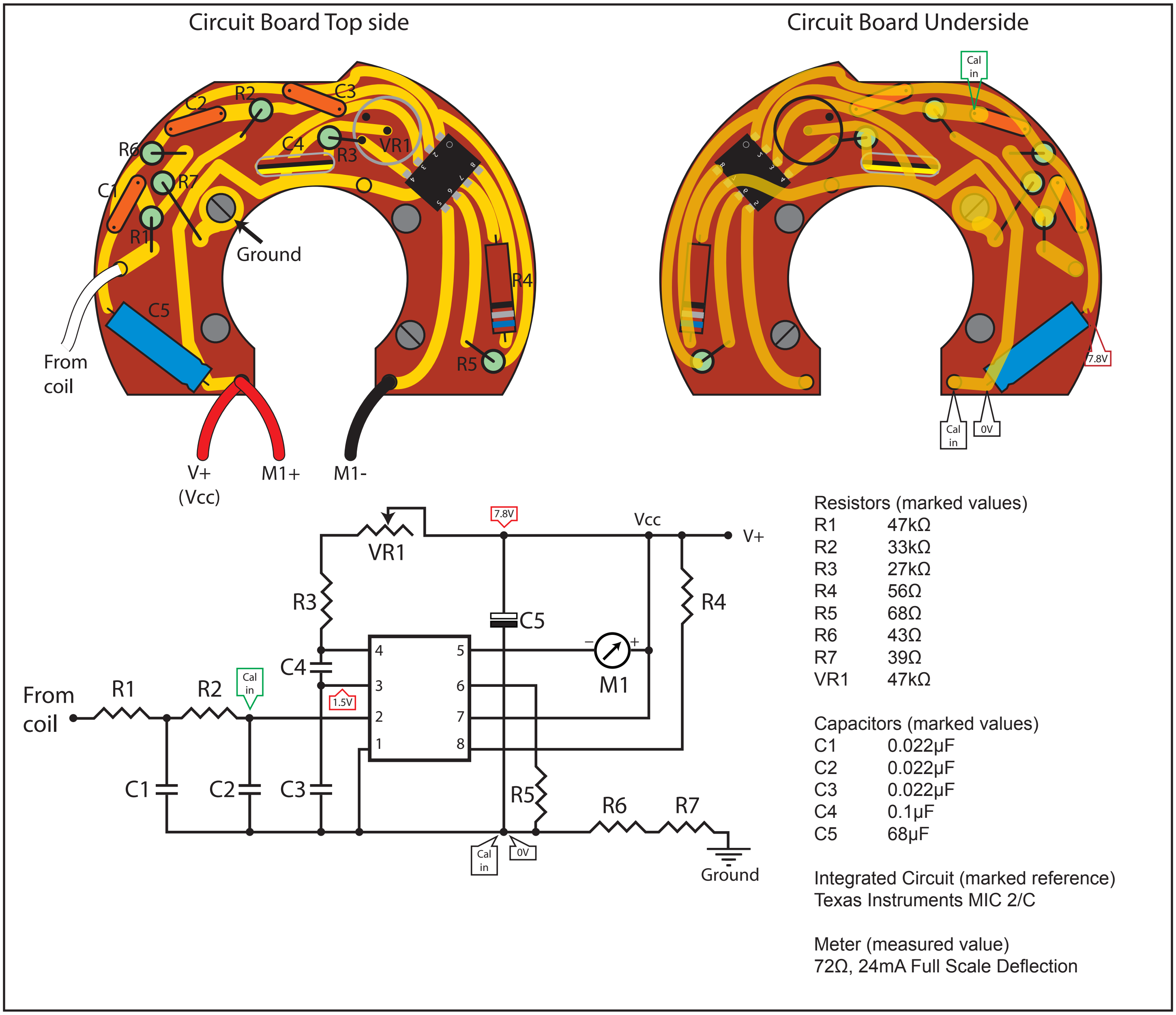


Fig. 5. MIC 2/C Example 3.

The circuit layout and diagram for the RVC 1410/00 is shown in Figure 6. Note that the circuit traces and component positioning are not absolutely accurate. They are intended to give anyone working on the PCB an easy way to find their way around it. A picture of the real instrument is shown in Figure 7. The appearance of some components changed during production so may not always be identical to those in the example shown.

Referring to the circuit in Figure 6, even without full knowledge of the internal construction of the MIC 2/C, it is possible both surmise and determine by testing and reconfiguration, some operational understanding.

The MIC 2/C evidently has an internal voltage regulator that makes the tachometer immune to the normal system voltage variations of the vehicle. The vehicle voltage may be as low as 11V for an engine at idle but heavily loaded with a charging battery and running a number of accessories such as headlights, brake lights, turn signals and wipers (as it may be at a traffic light), or high as 14.5V for a lightly loaded alternator running at high speed on the highway in daylight. The IC does a very good job, tests showing that the voltage between V+ and R6 (Vcc) remaining at a measured 7.8V for input voltages ranging from 8.5V to at least 16V. The difference in voltage between the constant voltage Vcc and the variable input voltage V+ is dropped by R6 & R7. These are ½ Watt resistors of similar value, which together can dissipate 1-Watt. Why they have such odd and different values from one another in unknown, as is the reason for using two, ½-Watt types instead of a single 1-Watt, as has been used for R4.



Resistors (marked values)

R1	47kΩ
R2	33kΩ
R3	27kΩ
R4	56Ω
R5	68Ω
R6	43Ω
R7	39Ω
VR1	47kΩ

Capacitors (marked values)

C1	0.022µF
C2	0.022µF
C3	0.022µF
C4	0.1µF
C5	68µF

Integrated Circuit (marked reference)
Texas Instruments MIC 2/C

Meter (measured value)
72Ω, 24mA Full Scale Deflection

Figure 6. The layout and circuit diagram for the RVC 1410

The purpose of R4 is unclear. The current that passes through it is inversely proportional to the current in M1. This happens to keep the current draw through the circuit almost constant, which would aid voltage regulation.

The purpose of R5 is uncertain too. However, it has almost exactly the same resistance as M1 and the current that passes through it is the same as that in M1. While it is not directly connected to M1, it is certainly in the same current path, perhaps in the source (emitter) of the transistor that drives M1. This means that M1 and R5 could be swapped in any application where there was a need to drive a meter movement that is, for any reason, connected to the negative side of

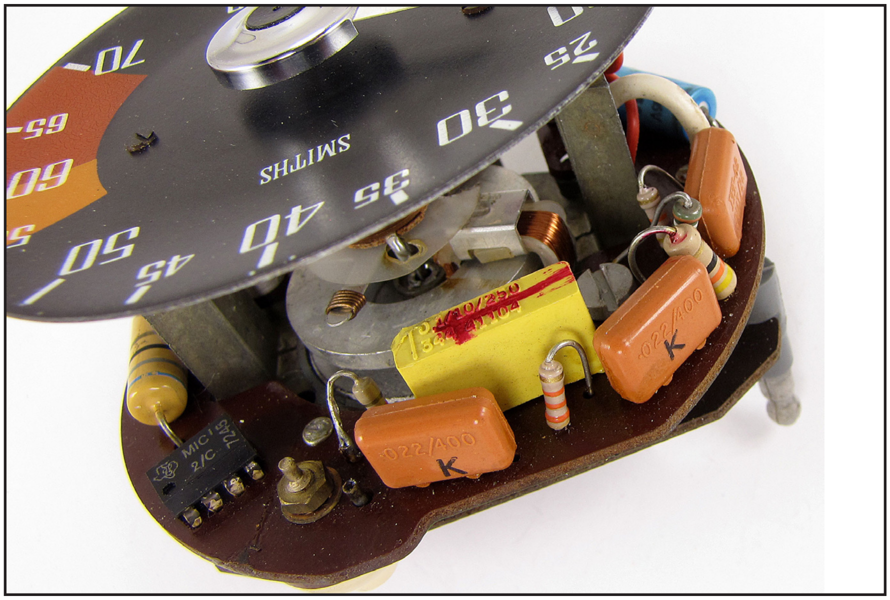


Fig. 7. Internal view of the RVC 1410.

the power line.

As described earlier, the peak pulses illustrated in Figure 1 can be close to 300V, a level that would damage most integrated circuits. The purpose of R1, C1, R2 and C2 is therefore to reduce the amplitude of the trigger pulse and shape it somewhat so as to filter out the high frequency components of the waveform. Not withstanding the fact that the vehicle from which the oscilloscope traces were taken requires a tune-up, the upper waveform in Figure 8 shows pulses picked up at an ignition coil primary at fast idle, while the lower waveform, read at pin 2 of the IC, shows how R1, C1, R2 & C2 integrate the signal, reducing the peak voltage to a safe 7V.

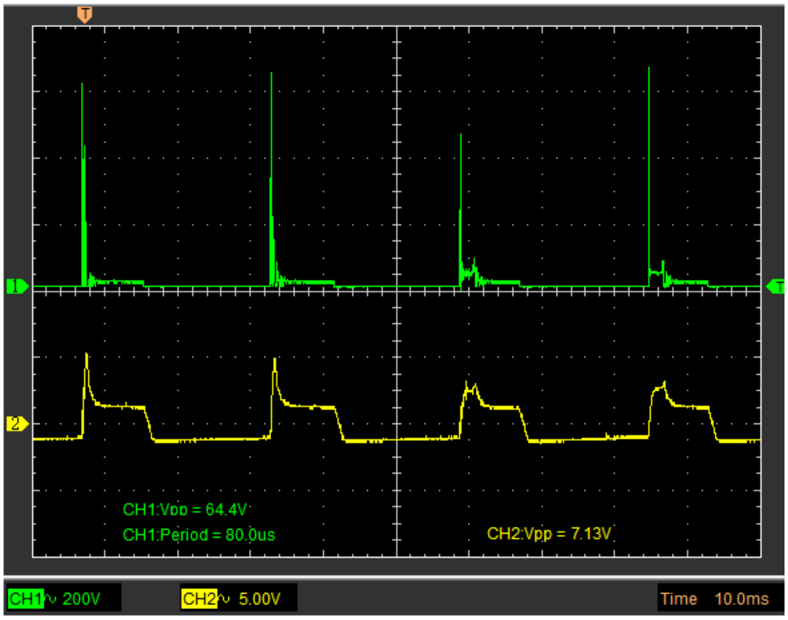


Figure 8. A pulse at the ignition coil primary (top) is processed to a safe level (bottom) at IC pin 2 by R1, C1, R2 and C2.

The pulse at pin 2 triggers the start of another pulse at pin 3, the duration and timing of which is determined by R3, VR1 and C4. Figure 9, upper waveform, shows a 40Vpp, 100 Hz test signal applied to R1 with the resulting output at pin 3 in the lower trace. Note that in this and subsequent oscilloscope images, the lower waveform traces are those across M1, and with reference to Vcc, to which M1+ is connected. Note also that there is a consistent delay (d) of 400μs between the ac test pulse heading into positive territory and the initiation of the output pulse. Current flows in M1 when internal transistors in the IC switch on and pull M1- toward 0V. Note how the pulse ‘On’ period starts with it going briefly 8V below Vcc to the 0V level then coming back to about -2.5V until the end of the pulse. The pulse lasts for about 2.8ms and no more are produced until a new input trigger pulse arrives.

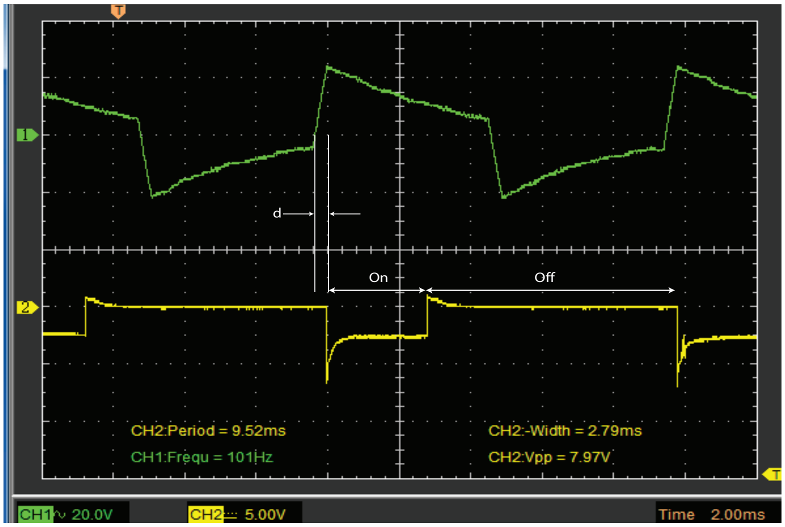


Figure 9. A 100 Hz test waveform (top) applied to R1 results, after a short delay, in a negative 2.8ms pulse (bottom) generated at pin 5.

In marked contrast to the 555 timer, discussed later, the output pulse triggered by pin 2 does not remain high even if pin 2 is held low, a fact which allows the trigger pulse, as conditioned by R1, C1, R2 and C2 to remain low, as shown in Figure 8, in between ignition pulses.

Figure 10 is similar to Figure 9 except that the input frequency has been doubled to 200 Hz. Note that the output pulse ‘On’ time remains the same (within measurement error) but the ‘Off’ time is less because new trigger pulses arrive more frequently.

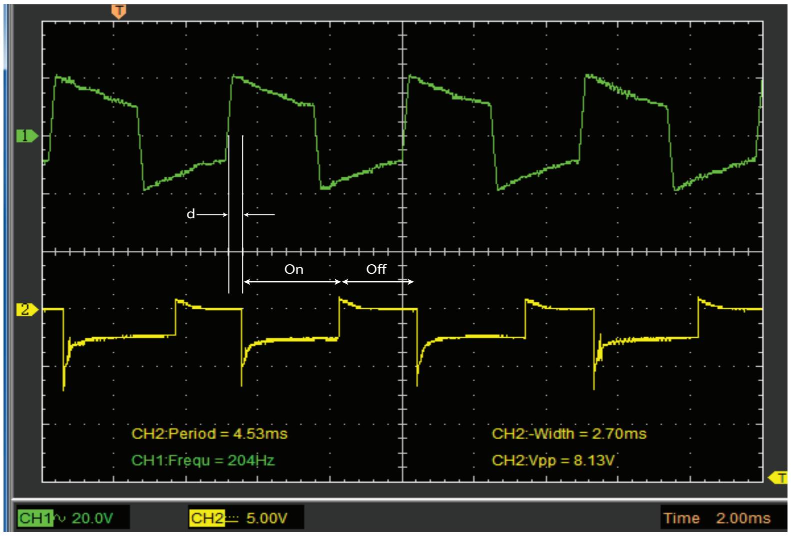


Figure 10. A 200 Hz test waveform (top) applied to R1 results in no substantial change in the ‘On’ time (bottom), but a shorter ‘Off’ time.

If, as shown in Figure 11, if the frequency is again doubled, this time to 400 Hz, the input pulses arrive at the rate of every 2.5ms (1 ÷ 400) and become more frequent than the pulse width of about 2.8ms. Note how input pulse A triggers an output pulse but that input pulse B is ignored because the output pulse is incomplete. Once the output pulse is over, it is ready to be triggered by input pulse C but again, the following input pulse D is ignored. The effect is that once the vehicle produces more than 357 sparks per second (or so) (1 ÷ 0.028), (which is to say it is running at 12,000 rpm for a 4-cylinder car, or 8,000 rpm for a 6-cylinder, or 6,000 rpm for an 8-cylinder) with the standard values of C1 (0.1μF) and of VR1+R3 (measured at 47kΩ), then the tachometer will suddenly begin to read half the correct engine speed.

Comparing Figures 2B and 2D, it can be seen that broadening the pulse width resulted in a higher reading on the gauge. The converse is true too; reducing the pulse width lowers the gauge reading. VR1 is a variable resistor and when its value is changed, so is the time required to charge C4. In Figure 12, a 47kΩ resistor has been temporarily placed in parallel with VR1 + R3 effectively halving the value of resistance charging C4. C4 thus charges twice as quickly and the output pulse width is also halved from 2.8ms to 1.38ms.The result is that the output pulse is now complete before a new trigger pulse arrives and so, unlike the case shown in Figure 11, in Figure 12, every input pulse (A, B, C, D and those that follow) triggers an output pulse. With the 'On' duration of the tachometer halved current flows in M1 for only about half as much time, so the tachometer will now read 50% of its correct value across its whole range. A similar test was done where a second 0.1μF capacitor was connected in parallel with C4, making the total value 0.2μF. This action effectively doubled the capacitance charged via VR1 + C4 and along with it the time to charge it. The output pulse width also doubled as did the gauge reading for input frequencies below about 180Hz, after which a similar pulse skipping phenomenon to that shown in Figure 11 was observed.

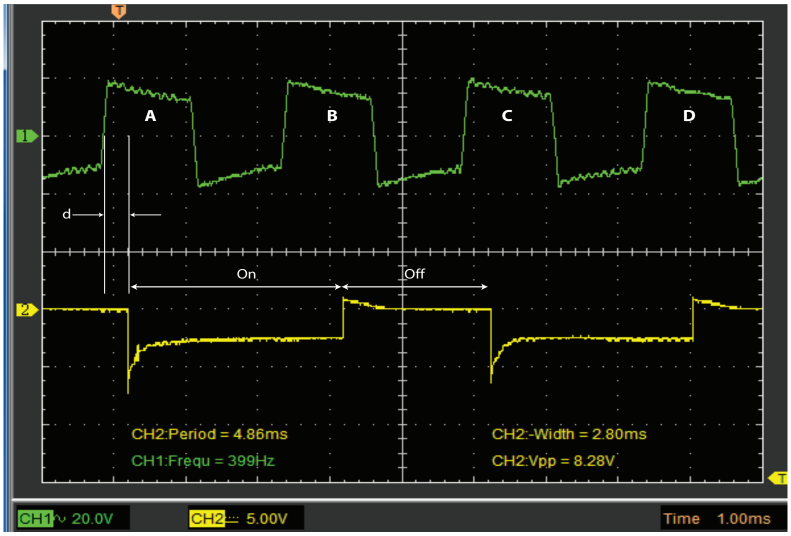


Figure 11. A 400 Hz test waveform (top) applied to R1 results in every other input pulse being ignored (bottom).

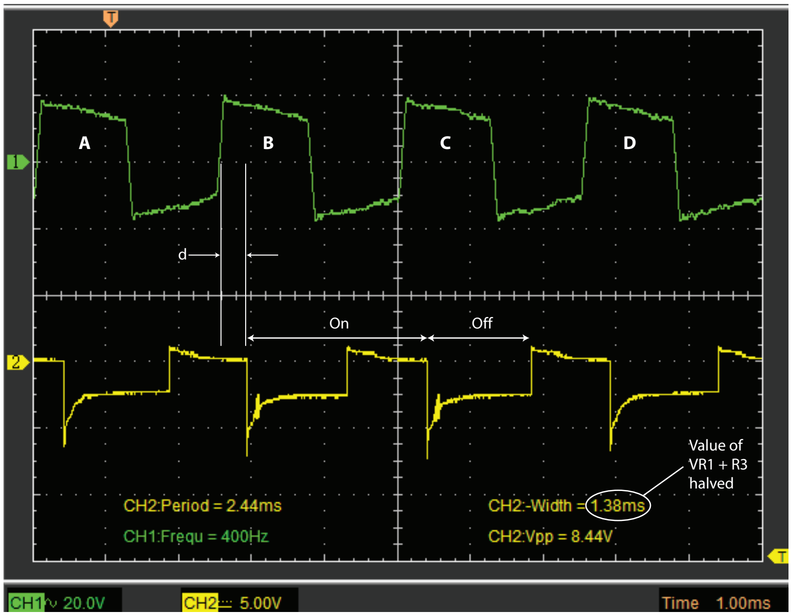


Figure 12. The same input waveform as in Figure 11 is applied but the VR1+R3 resistance in halved, resulting in every input pulse triggering an output pulse.

So it seems that so long as C4 is charging, the pulse outputted at pin 3 remains and the trigger input at pin 2 is immune to being further triggered by any following signal. Once C4 reaches a certain proportion of Vcc, pin 4 detects this, and (1) switches the pulse at pin 3 off, and (2) again opens pin 2 up to being further triggered and (3) discharges C4 via pin 3. It is also interesting to note that when correctly calibrated, the combined value of VR1 and R3 is about 47 kΩ, the same value as the single fixed resistor Smiths substituted for them in the 00AF. Further, with R3 + VR1 = 47 kΩ the pulse width produced at pin 3 is 2.8ms long and, should the pulse width need to be changed, the effect of the combination of C3, R3 and VR1 can be calculated as:

- C3 μF × (R3+VR1) kΩ ÷ 1.68 = Pulse width in ms.

C4 seems to sit on a stable base voltage of 1.5V at pin 3, held in check from small voltage variations by C3. Increasing the value of C3 by 5 fold didn't obviously affect the tachometer, tests being made of calibration, response time and the delay (d) shown in Figures 9 through 12.

C5 is a large electrolytic capacitor used to help maintain a steady Vcc voltage. It acts like a power reservoir, filling in for short power demands from the IC to which its internal voltage regulator may be too slow to react. Ideally, there should be as small a resistance as possibe between it and the IC and so should be placed as close to the IC as pratical, which in this case, in contrast to the RVC 1410/00AF described below, it is not.

Thus, in summary, a signal, conditioned by R1, C1, R2 and C2, is applied to pin 2 and triggers the start of a pulse that is outputted at pin 3, where it drives the meter movement M1. It also blocks pin 2 from being further triggered by any signals from the coil. The pulse's width is a function of the time it takes to charge the capacitance of C4 via the combined resistance of R3 and VR1. Once pin 4 detects that C4 has reached a certain state of charge, it turns the pulse at pin 3 off, opens pin 2 up to further triggering and discharges the capacitor via itself and pin 3. Frequent trigger signals result in more pulses being generated at pin 3, causing M1 to read higher. Varying the width of the pulse using the calibration variable resistor VR1, will also change the average current flowing in M1. M1 has inertia that prevents its indicator needle bouncing back and forth with every pulse, so instead it tends to read a mean or average value.

Those familiar with the 555 timer will note, that many of the operational characteristics of the MIC 2/C seem similar to the 555 timer IC.

RVC 1410/00AF

The electrical circuit for the RVC1410/00AF is almost identical to that for the RVC 1410. The layout and construction, however, are very different, as can be seen by comparing Figure 7 and Figure 13.

The 00AF has been constructed on a ceramic substrate rather than a conventional circuit board. 'Ceramic" in this case is probably alumina or beryllium oxide, both of which are electrical insulators but have good thermal conduction properties. These materials are hard to cut and drill, so that most of today's production is 'machined' using lasers, a technology probably not readily available at the time this tachometer was conceived. This board has no holes and is bonded to a metal plate.

The capacitors and IC are surface mounted onto the board and all resistors are printed using thick-film technology. The resistors can be seen by turning the board at certain angles to the light, where they may show as rectangles on the board surface that contrast in reflectivity a little with the ceramic. The ceramic is white but has a dark coating, which in Figure 14, has been lightened to better show the carbon black resistors.

The circuit operation is as per the 1410, but it is worth noting the important differences. Note that because the resistors are unmarked, their values had to be measured. Although in some cases they may appear to be different from those of the RVC 1410, they may be within the same tolerance band.

Referring to the circuit in Figure 14, and comparing it to that in Figure 6, there is no significant difference in the input components R1, C1, R2 and C2.

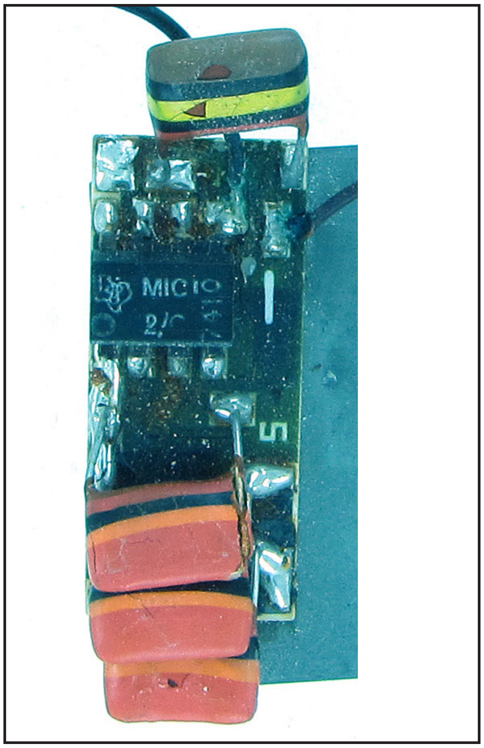


Fig. 13. RVC 1410/00AF circuit board. (C5 removed)

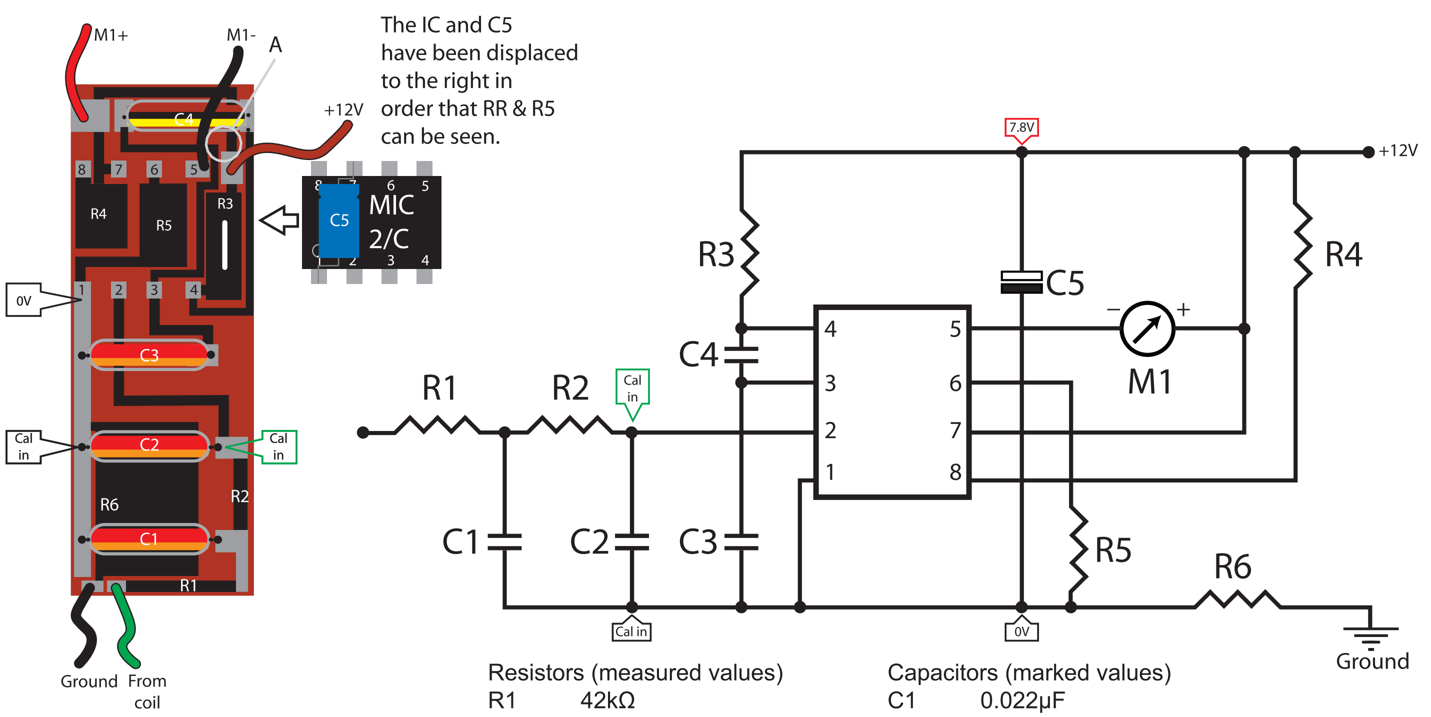
C3 is also identical in value. C4 remains a 0.1μF but is charged via a single resistor R3 of 47kΩ value rather than a fixed resistor (R3) and variable resistor (VR1) combination. However that when the RVC 1410/00 is properly calibrated, VR1 is set to about 20kΩ, making the total resistance, when added to R3, also 47kΩ.

Note that M1 requires less current to drive it to full scale deflection (FSD), which means that the total current consumed by the circuit is also much less. In fact, the reason the FSD of M1 has been reduced is probably so that the high wattage resistors found in the 1410/00 (R4 and the combined R6 & R7) can have, in the form of R4 and R6 in the 00AF, lower power capability and thus be more easily fabricated as thick-film devices.

It was surmised that the function of R4 in the 1410/00 was to keep the circuit current constant irrespective of the current draw of M1. This holds true in the 00AF in which R4 is over 200% higher in value because it needs to draw less compensating current in inverse proportion to the lower current flowing in the higher resistance M1.

Again comparing the 00AF with the 1410, because M1 is more sensitive and the pulse length produced by R3 and C4 is the same, something must change to reduce the current for a given RPM. That is achieved by increasing the value of R5, which is in the same current path as M1.

C5 isa little lower in value than its 1410/00 counterpart but is better placed in very close proximity to the



The IC and C5 have been displaced to the right in order that RR & R5 can be seen.

Resistors (measured values)

R1	42kΩ
R2	33kΩ
R3	47kΩ
R4	122Ω
R5	192Ω
R6	162Ω

Capacitors (marked values)

C1	0.022μF
C2	0.022μF
C3	0.022μF
C4	0.1μF
C5	47μF

Integrated Circuit (marked reference)
Texas Instruments MIC 2/C

Meter (measured value)
160Ω, 10mA Full Scale Deflection

Figure 14. The layout and circuit diagram for the RVC 1410/00AF

MIC 2/C (removed for photographic purposes in Figure 10 but drawn in place in Figure 11).

Like the 1410, the 00AF has a mechanical zero adjustment regulator on the meter movement, but unlike the 1410, there is no electrical means to calibrate the 00AF. C3, a component critical to the accuracy of the tachometer, is not a tight tolerance device. Figures 13 & 14 show R3 to have a slot down the middle. Close examination show that the slot has been ground out of R3. This is doubtless how the tachometer was calibrated in the factory. If R3 were manufatured a little lower in value than required, then by removing carbon film, its value could be increased the correct amount. A few examples of the instrument have also been found with bent fingers on the metal cup that is an extension of the magnet and which surrounds the moving coil, see Figure 15. They are bent in the area the coil would arrive at if the needle were between the 4000 and 5000 rpm position, suggesting some attempt was made to get the instrument to read accurately at the highest practical engine speeds. Later examples, like that in Figure 17, show the fingers under-cut at the bottom, which would make adjustment by bending easier.

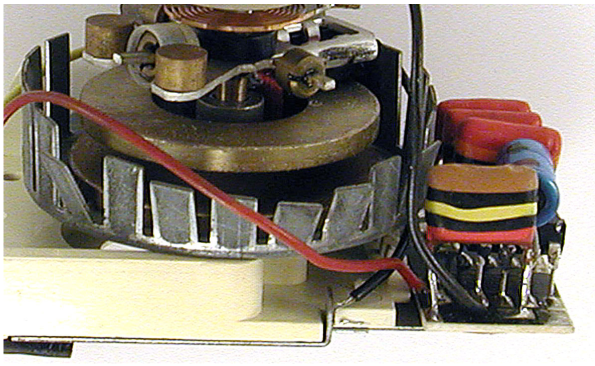


Fig. 15. RVC 1410/00AF showing bent magnetic cup fingers.

With the circuits so similar, why is the RVC 1410/00AF so much less reliable than the RVC 1410? It is of course dangerous to make sweeping assumptions based on very few examples, but failure of the circuit board seems to be the culprit. In at least a 2 examples, short-circuits were found on the board in between pin 5 and pin 3. The cause was not determined but contaminationby conductive particulate, dendrites and tin whisker growth are potential candidates. Cleaning the board with a small stiff brush soaked in denatured alcohol (methylated spirits) in the area indicated as ‘A’ in Figure 14, removed the short-circuits, but did not remedy the non-working tachometers. The MIC 2/Cs were subsequently removed and inserted into a working RVC 1410, which unfortunately showed that the ICs had failed. Hence it seems worth the effort of cleaning the board on any failed RVC 1410 /00AF in the hope that this action may remove a fault that has not yet led to failure of the IC.

Changing a 4-cylinder Tachometer to a 6 or 8-Cylinder Type

There are a couple of ways to change the more commonly available 4-cylinder version of these tachometers to work on 6 or 8-cylinder cars. The method I chose to describe in *MGB Electrical Systems* was selected because I judged it the most simple and it happened to work, even though I was surprised that it did. Because 6-cylinder cars produce 1.5x as many sparks per minute as a 4-cylinder car and 8-cylinder cars produce 2x as many, then if used without modification, a 4-cylinder tachometer reading would be 1.5x or 2x higher respectfully than it should be.

Changing the Meter Current

My recommendation in the book *MGB Electrical Systems* was simply to put a resistor in the meter wire that would cut the current by 25% or 50%. Taking the 8-cylinder example: if, when running at 2,000 rpm, the 4-cylinder tachometer reads 4,000 rpm, then adding some resistance to the meter circuit is an obvious way to reduce the reading to the correct value. That's fine, but if the 8-cylinder car were running at 5,000 rpm, then this method would presume that the tachometer was actually capable of reading the coil signals from a 4-cylinder car running at 10,000 rpm. This not only proved to be the case, but the calibration remained good up to 5000 rpm, the highest anticipated for a V8, a credit to the sound Texas Instruments design. It also computes (just!), but those wishing to run V8 engines at higher RPMs, should consider decreasing the pulse width as described below and illustrated in Figure 12. In order to work correctly the width of the pulse driving the meter must be shorter than the frequency of the ignition pulses triggering it. The pulse width on these instruments is about 2.8ms and at 5,000 rpm, the spark occurs every 3.0ms, so this method goes to the edge of the theoretical maximum.

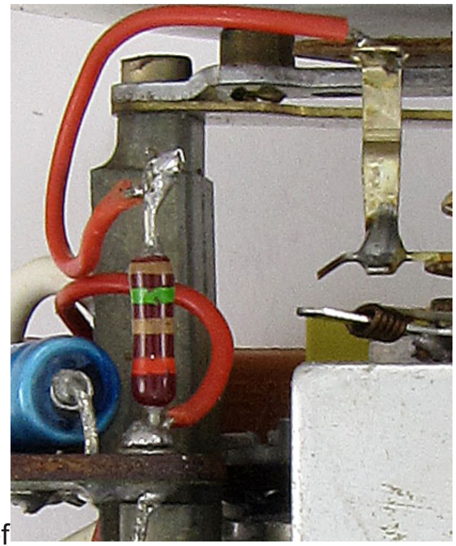


Fig. 16. RVC 1410 with a fixed resistor in series with the meter.

It terms of an actual value for an RVC 1410, a 150Ω resistor can be placed in series with the meter M+ wire as shown in Fig 16. Final fine adjustment for use on 6 or 8-cylinder cars is then made using VR1, already on the board in the position shown in Figure 6. Most, but not all of these instruments will be found to have a hole in the back, covered with a rubber plug, that allows adjustment of VR1 with the rear case in place.

The RVC 1410/00AF requires a variable resistor. This was installed in the instrument shown in Figure 17 by epoxy bonding a small 1kΩ potentiometer to the plastic base and wiring it in the red circuit between the PCB and the meter.

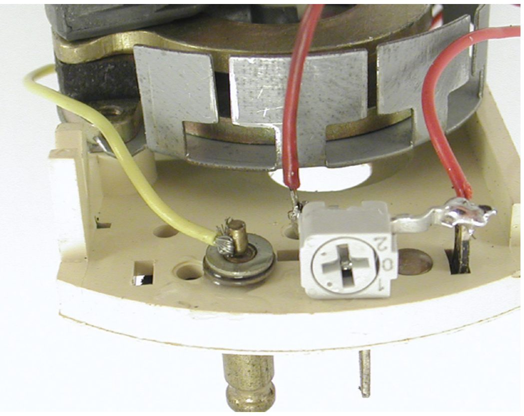


Fig. 17. RVC 1410/00AF a variable resistor in series with the meter.

This method of changing the gauge reading is basically that illustrated in Figure 2C, although in that example the amplitude of the pulse feeding the meter was increased, whereas in this instance we are decreasing it.

Changing the Pulse Width

The other method of changing the calibration is to change the pulse width, as per the representation in Figures 2D and Figure 12 and as does VR1 in the RVC 1410. There are a couple of ways to do that and the choice comes down to practicality.

On the 1410/00AF tachometer, C4 is quite accessible (see the layout diagram in Figure 14). Removing it and substituting a 0.05μF will make the tachometer suitable for use on 8-cylinder cars. In theory, replacing C4 with a 0.075μF capacitor would work for 6-cylinder cars but it may be hard to find this value and be necessary to use a 0.05μF and a 0.025μF wired in parallel. Although not impossible, removing and replacing C4 is a little tougher on the 1410, for which the same substitute capacitor values would be used. Buy the smallest capacitors you can with a 20V rating or greater.

The alternative method is to decrease the value of the resistor(s) that charge C4. For the 1410/00 tachometer, the combined value of VR1 and R3 need to be reduced to 35.25kΩ for 6-cylinder operation or 23.5kΩ for 8-cylinder cars. These values are most easily obtained by putting a 47kΩ resistor in parallel with VR1 and R3 for 8 cylinder cars. For 6-cylinder cars, a 141kΩ resistor is required, but that is not a common value and so a 150kΩ can be used and VR1 adjusted anti-clockwise a tad until the measured resistance of the whole network is 35.25kΩ. This method is fairly simple to execute but will make VR1 less linear and thus a little 'twitchy' to adjust. One alternative is to swap out R3 for a 10kΩ resistor and adjust VR1 until the combined total is either 35.25kΩ or 23.5kΩ as required. If you don't like the idea of removing R3, you could instead wire a 15kΩ resistor across it to form a parallel combination of 9.6kΩ.

The same 23.5kΩ and 47kΩ resistances are needed for the 1410/00AF, but again for 6-cylinder operation, finding a 141kΩ resistor to put in parallel with R3 is almost impossible, but you may find a 140K from a supplier of 2% tolerance resistors, which is fine. The 47kΩ value required for 8-cylinder use is easy to source. The resistor will have to be installed between pins 4 & 7 of the IC, which means bringing a soldering iron to it. To prevent thermal damage to the IC, use a iron with a small bit suitable for electronic work and be as quick as possible in soldering to each pin, pausing to let the IC cool down between each of the two connections.

Checking and Adjusting Calibration

As previously mentioned, the 1410/00 has a variable resistor VR1 for adjusting the instrument and that while the 1410/00AF has no such device, some degree of adjustment may be possible buy bending the magnetic cup fingers as shown in Figure 12, adding a small amount of capacitance in parallel with C4 to increase the reading or adding a little parallel resistance to R3 to decrease it.

First, of course, it is necessary to ascertain whether or not any adjustment is necessary. How accurate you wish the tachometer to be may dictate the preferred method. There is no real reason why a 1410/00AF should go out of calibration because R3 and C4 are not under any stress in use and should not be prone to change over time. In the case of the 1410, the very fact that it can be adjusted may mean that it has been.

With the assistance of data taken by a passenger who can record the gear being used (including overdrive if applicable), the tachometer reading and that of the speedometer, a road test may be good enough. The engine speed in each gear for the particular vehicle should be readily available and can easily be compared to the data recorded. Remember that any changes to wheel size and/or differential gearing will render the book data for speed in each gear inaccurate. It's also worth verifying first the speedometer is accurate, a task easily achieved today using a portable GPS (Sat-Nav) device.

A portable rev counter instrument or another known-to-be-accurate Smiths tachometer could also be used to compare readings with the instrument under test.

Where necessary, the method I prefer allows verification and calibration all in one step by using a computer or MP3 player to drive the tachometer with pseudo ignition signals. There is some risk to both the tachometer and the MP3 player when using this method, I have tried it with a number of computers and a BlackBerry phone that can play MP3 files, with no problems, but I can't say that every device capable of playing MP3s would work. Fortunately, the tendency to replace phones and other MP3 capable devices with the latest models means that there are plenty of old devices lying in drawers or available very inexpensively. As far as the tachometer is concerned, it only requires a peak voltage of 1V to trigger it and you are connecting directly to the IC, so be gentle and always start from a low volume and raise it slowly.

The signals from the ignition coil come at rates that equate closely with the audio range, and so MP3 files provide an easy way to emulate them. The word emulate, rather than simulate, is used here because the MP3 signal input does not imitate the ignition pulse, it just drives the tachometer at the same rate. However, since the tachometer looks for the initial signal spike before blocking off everything that immediately follows, the MP3 signal produces the same tachometer reading as a true ignition pulse of the same frequency.

The frequency of the ignition pulses per engine revolution depends on the number of cylinders the car has. A 4-cylinder car with a 4-cycle engine produces 2-sparks per revolution, a 6-cylinder 3-sparks and 8-cylinder 4-sparks. The table shows some equivalent frequencies in Hz (cycles per second) to the RPM (engine revolutions per minute) for each type of car.

	Frequency (Hz)		
RPM	**4-cyl**	**6-cyl**	**8-cyl**
1000	33.3	50.0	66.7
3000	100.0	150.0	200.0
5000	166.7	250.0	333.3

These 3 test points should be enough to calibrate the instrument correctly.

Note that the texts of the above frequencies are actually hyperlinks to a web site from which you may download the MP3 files for each frequency. You may also download a ZIP file containing all 9 frequencies from here. Each file is a high output, almost square, signal with a duration of 1 minute. If 1 minute isn’t long enough, most devices that play MP3 files have a ‘repeat’ feature, which makes it repeat the same song, or in this case tone, over and over until the Stop button is pressed.

In order to get the signal from the player to the tachometer you’ll need a jack-plug of the same size (either 2.5 mm (0.1”) or 3.5 mm (~ $^{1}/_{8}$”)) as that used for connecting ear-buds or headphones to it. If you have an old earpiece or other listening instrument, you could cut the wire off that and use it to connect to the tachometer. Otherwise you can buy a cable with a jack plug or a separate plug.

Figure 18 shows a diagram of such a jack plug. Most are stereo, but only one channel needs connecting, that’s either the tip or the ring just behind the tip. The earth connection is the one that would normally go to the cable shield and connects to the main stem of the plug. I advise temporarily soldering the wires from the jack plug to the circuit board. At the tachometer, the green wire in Figure 18 goes to the green ‘Cal in’ point shown in Figures 6 & 14. The black jack-plug wire goes to 0V (black ‘Cal in’) point, *not* to the grounded metal frame of the tachometer where you will be connecting the negative power input wire.

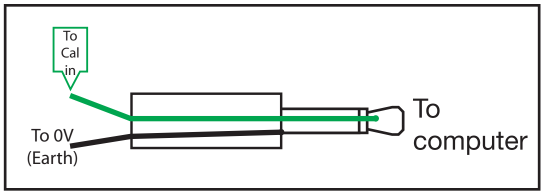


Fig. 18. To calibrate using the method described here, a plug is required that can be used with an MP3 player.

It was mentioned earlier that some meter movements suffer from ‘stiction’, which may not be noticed when the tachometer is subjected to the vibration of a moving car. However, when calibrating on a stationary workbench, some tapping is recommended just to check that the needle has found its final position.

- Step 1

Start by attaching power wires to the tachometer. At the MP3 player or computer, check that you can play the 5,000 rpm MP3 file appropriate to the number of cylinders of your vehicle, and then turn the volume down fairly low. Plug the tachometer into the player and slowly raise the volume until the tachometer starts responding to the signal.

If necessary, adjust the 1410/00 variable resistor RV1 so that it reads 5,000 rpm.

With the 1410/00AF, if you’re happy that it reads close enough to 5,000 rpm, then go on to the Step 2, otherwise you could try making an adjustment by bending the fingers on the cup close to where the needle is pointing as per Figure 15. This should reduce the reading. If you wish to increase it, then you may have a problem, because bending the fingers toward the meter movement’s coil could interfere with its movement.

The other solution is to place a capacitor in parallel with C4 to increase the reading or add a resistor in parallel with R3 (between pins 4 & 7 of the IC) to decrease its value. Use the following table as a guide to what

Actual Reading	**Capacitance to be added**		
	µF	**nF**	**pF**
4,000	0.022	22	22K
4,200	0.015	15	15K
4,400	0.015	15	15K
4,500	0.01	10	10K
4,600	0.01	10	10K
4,800	0.0047	4.7	4.7K

The capacitance values are given in three formats because capacitors may be marked in any of those listed. Note that some of the values of adjacent rows are identcal because the nearest standard, rather than calculated, values are given.

Actual Reading	**Resistance to be added**
5,200	1MΩ
5,400	560kΩ
5,500	470kΩ
5,600	390kΩ
5,800	270kΩ
6,000	220kΩ

values to add to obtain a 5000 rpm reading:

- Step 2

Once the 5000 rpm point is correctly calibrated, call up the appropriate MP3 for 1,000 rpm. If the tachometer doesn't respond at all it may be necessary to increase the MP3 player's volume a little. If the tachometer meter movement hasn't been previously disturbed, it should read correctly at 1,000 rpm. If not it will be necessary to move the zero adjust lever at the back of the instrument.

The lever, arrowed in Figure 19, is located just behind the dial face. It can be quite fragile and at the same time quite stiff to move. Moreover, it is located close to some even more fragile parts of the meter movement, so care is needed in adjusting it. The direction of movement of the lever is intuitive, moving it also moves the indicator needle above it in the same direction. If it is found necessary to move the zero adjust lever, then Steps 1 & 2 of the calibration process will have to be repeated until one or other no longer needs changing.

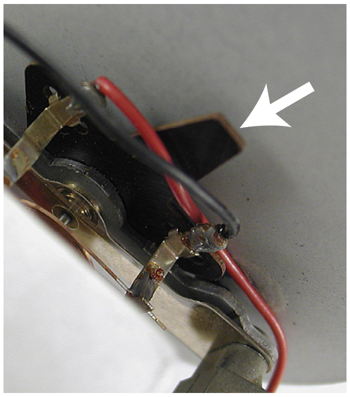


Fig. 19. The zero adjust lever is located just behind the dial face.

- Step 3

Once the 5,000 and 1,000 rpm points are calibrated, use the applicable MP3 tone in order to check that the 3,000 rpm point, which is half way between them, is also correct.