Vintage Radio

By John Hunter

Above: an assortment of vibrators. The large box shaped unit with multiple contacts was used in a high power 60Hz inverter.

A practical guide to vibrator power supplies

Most people think switchmode power supplies are a relatively recent technological development. Well, they're not. They were devised long before transistors were developed. Vibrator power supplies in valve car radios were the first switchmode power supplies and they were devised way back in the early 1930s. Here's a quick run-down on the various vibrator types that were used, together with details on how to service and replace them.

BEFORE VIBRATORS were developed, the first valve car radios relied on a motor-generator to provide the HT from the car battery. The vibrator was a big improvement – tiny and highly efficient.

This article is focussed mainly on servicing these apparently simple devices. To the vintage electronics enthusiast, a vibrator power supply can be a source of frustration. All too often, what is seemingly a simple circuit fails to operate reliably, if at all. However, with a proper understanding of circuit operation, this need not be so.

The subject of vibrator power supplies is an extensive one and it is impossible to cover all aspects here. Interested readers should therefore make use of the references listed at the end of this article. In particular, the September and October 2003 issues of SILICON CHIP are recommended for those unfamiliar with the topic.

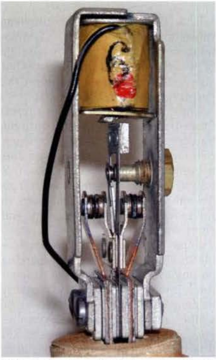
What is a vibrator?

Basically, a vibrator is an oscillating mechanical switch. It allows a transformer to be used with a DC supply by providing the DC-to-AC conversion necessary to drive the transformer. The transformer's AC output can then be used directly or it can be rectified if DC is required.

The best known vibrator application is in a valve car radio power supply. Such supplies typically produced around 200V DC when powered from the car's battery. Another application is where 240VAC appliances are operated in a vehicle or from a DC home-lighting plant.

Background

The first generation of car radios used the car's battery for the valve heaters but high-voltage "B" batteries (typically 135V) had to be provided for the plates and screens. However, it's easy to imagine the frustration of having to continually replace expensive "B" batteries while a fully-charged 6V



This photo shows the internal parts of an Oak series-driven, non-synchronous vibrator. Note the coil contact adjusting screw on the righthand side.

Built by the author, this 12V DC to 240VAC power supply uses an Oak non-synchronous vibrator and is based on the circuit shown in Fig.1.

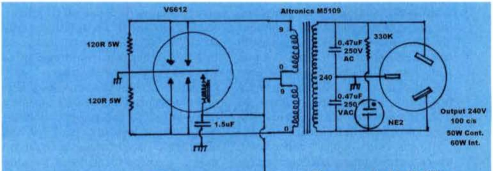


Fig.1: a typical 12V DC to 240VAC inverter circuit using a vibrator with a series-driven coil.

or 12V battery was already in the car.

So in 1932, P. R. Mallory & Company (of later Duracell fame) produced the first commercially-available vibrator power supply for car radios, under the "Elkonode" trademark. Its compact construction and quiet operation virtually eliminated motor generators and "B" batteries from car radios almost overnight.

Other manufacturers, such as ATR, Radiart, Utah and Oak, were also prominent players, each contributing to improvements in the technology. The first Mallory design was essentially a buzzer interrupting the primary current in a transformer at a frequency of 300Hz. A gaseous rectifier then provided 135V DC from the transformer secondary. Utah subsequently introduced full-wave operation which quickly became standard. A frequency of 100-150Hz also became the standard for most radio vibrators.

Series & shunt drive

Australian vintage radio restorers are fortunate in that most set manufacturers used an Oak vibrator. This type of vibrator was patented in the USA in 1934 and was made locally by AWA's MSP (Manufacturers Special Products) component division. Also commonly found are Ferrocart branded vibrators which were an Electronic Industries Ltd product and which were largely confined to their own brands such as Air Chief and Astor.

The importance of this is that the Oak vibrator has a series-driven coil. That is, the driving coil is switched by its own low-current contact. One advantage of this is that the reed will vibrate independently of the condition of the transformer switching contacts. Fig.1 & Fig.2 show how the reed is driven.

By contrast, the Ferrocart type of vibrator shown in Fig.3 is shunt-driven. This is the most common vibrator type used overseas. The driving coil shares the transformer switching contacts and while its simpler construction might seem advantageous, it will not start if there is any oxide or film on the contacts. And until it starts, the contacts won't be cleaned by the wiping action so it's a catch 22 situation.

Due mainly to its separate driving contact, the Oak/MSP type has turned out to have exceptionally good reliability. Even if the transformer contacts are worn or out of adjustment, it will start and produce an output. Shunt-driven types, on the other hand, simply fail to operate.

DC-to-AC conversion.

The inverter circuit of Fig.1 is one of my own designs but is typical of those that existed in the era. In this case, the vibrator has extra paralleled

This wartime advertisement shows the inner workings of an English vibrator that was based on Oak's patents.

contacts to obtain an increase in power rating. This type is known as a "dual interrupter".

However, contrary to expectation, the rating is somewhat less than double. This is because it's impossible to ensure the paralleled contacts open and close at exactly the same time over the life of the vibrator. In practice, better current sharing is obtained if the transformer has two primaries, switched by the individual contacts.

Because a radio-type vibrator is used, the output frequency is 100Hz but for many loads this is unimportant. Larger inverters generally use a 50Hz vibrator.

The 120Ω primary damping resistors help reduce RFI (radio frequency interference) and contact sparking. They do not usually cause trouble as they are low-value resistors which do not drift, as do old carbon resistors in the kΩ and MΩ range. What's more, not all designs include them.

Note also that any paper capacitors on the low-voltage side of the vibrator can generally be left in place because any leakage will cause no ill effects. In this circuit, if the 1µF and 1.5µF RF filter capacitors were leaky, all that would happen would be a small increase in the current drain.

Conversely, on the secondary side of the transformer, the buffer capacitor (here shown as two series-connected 0.47µF capacitors) is critical. Leaving an original paper capacitor in circuit here is a recipe for damage. Because of the voltage it is subjected to, leakage is not only very likely but also destructive. If left in place, a leaky buffer capacitor will overheat the vibrator contacts and ruin their spring temper.

This means that any paper buffer capacitors should be replaced as a matter of course. The ideal kind to use is a high dV/dt type, given the sharp risetime of the waveform. It also needs to be of sufficiently high voltage.

The "KP" series of polypropylene capacitors available from WES Components are a good choice. It is possible to use other types in some circuits but only with a good understanding of the particular operating conditions.

The purpose of the buffer capacitor is to form a tuned circuit with the transformer at the vibrator's frequency, reducing its inductive effect and thus preventing contact arcing. Thus, it is important not to deviate from the original value. Incorrect tuning results in increased current consumption and short vibrator life.

Some texts claim that it is impossible to eliminate all contact sparking but my own experience is to the contrary. If the power supply is properly designed, no contact sparking will be visible at all. These power supplies are characterised by their ease of RFI filtering and even after 60 years, the vibrator contacts can still look like new.

Non-synchronous conversion

Having produced AC at the transformer's secondary, any standard rectifier circuit can then be used to produce the DC required for valve plates and screens. Conventional rectifier valves such as the 6X4 are typical but the 0Z4 gas rectifier was popular in American designs. By contrast, the 0Z4 was not manufactured in Australia, so few local designs used it.

The power supply circuit used in the AWA 946AZ car radio (Fig.2) was typical practice. It uses an Oak "non-synchronous" vibrator, as shown in one of the photos. (Editor's note: non-synchronous vibrators are also referred to as "asynchronous").

On the primary side of the transformer, L6 & L7 are chokes for further RFI filtering. Paper capacitor C27 needs to be replaced as a matter of

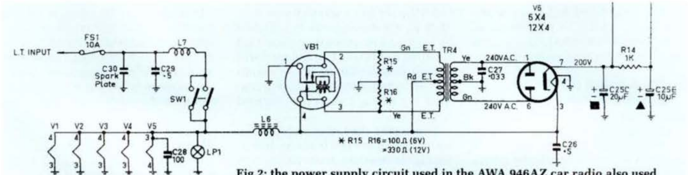


Fig.2: the power supply circuit used in the AWA 946AZ car radio also used an Oak non-synchronous vibrator. Capacitor C27 in this circuit should be replaced as a matter of course to prevent contact damage (see text).

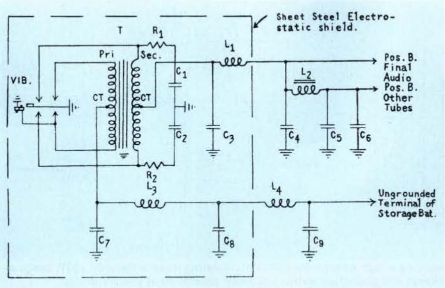


Fig.3: a Ferrocart circuit for a synchronous vibrator. Note the extra set of contacts which rectify the transformer's secondary winding output.

course (as detailed above), while C26 & C29 will cause no ill effects if leaky and can be left in position.

The replacement parts must be connected to the same tags as the originals, the earth connection points of the capacitors being particularly important. It is tempting with newer, smaller components to connect one lead to a closer earth tag, for example. However, because of circulating currents in the chassis, this new earth point may actually increase RFI. A lot of design work goes into the layout of an interference-free power supply.

Note that the vibrator symbol on Fig.2 shows a second winding on the driving coil which is short-circuited. Its purpose is to prevent arcing at the coil contact by slowing the rate of magnetic flux collapse when the contact opens.

The waveform of the transformer secondary across C27 is shown in Fig.5. Note that the input polarity is unimportant as the rectifier will automatically produce correct polarity at the output. This meant that in an era where positive-earth vehicles were just as common as negative-earth vehicles, a radio could be installed in either type of car without modification.

By the way, failing to include a fuse in the supply input lead can lead to a damaged transformer or vibrator if the buffer capacitor fails or if the vibrator contacts stick because of overload.

Synchronous conversion

Early on in the vibrator's development, it was realised that a second set of contacts synchronised with the primary contacts could be used for rectification. This is known as a "synchronous" vibrator. In simple terms,

This view inside a Ferrocart synchronous vibrator clearly shows the extra set of contacts that were used for rectification.

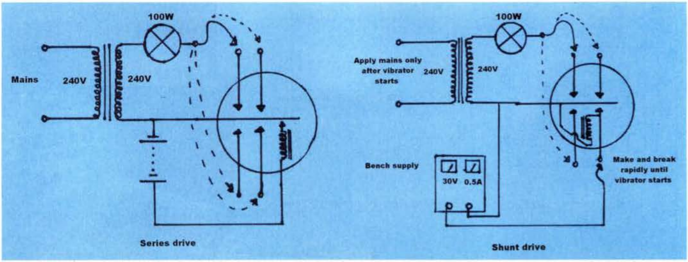


Fig.4: vibrator contacts can be cleaned by applying a high-voltage via a 240VAC isolating transformer and 100W lamp, as shown here (see text for details). DO NOT attempt this procedure unless you know exactly what you are doing.

the secondary contacts close at the same time that a conventional diode would conduct.

Fig.3 shows a synchronous circuit using a shunt-driven vibrator. If the secondary contacts are imagined as diodes, with their cathodes connected to the winding and their anodes earthed, it can be seen that this is a conventional full-wave centre-tap rectifier circuit. However, unlike the non-synchronous circuit, either the secondary or primary winding connections must be reversed if the output polarity is incorrect.

Again, buffer capacitors C1 & C2 will need to be replaced if they're original paper types. Generally, the secondary damper resistors, R1 & R2, will be OK because they are low-value types. They still need to be checked though, because if either C1 or C2 shorts, these resistors act as fuses, leaving the vibrator running with no buffer capacitance. However, the user is left none the wiser as the radio continues to play, albeit with an arcing vibrator headed for an early demise.

The additional rectifying contacts are visible in the accompanying photo of a Ferrocart vibrator. It's suitable for use in the circuit shown in Fig.3.

A variant of the synchronous vibrator is the split reed type. Here, the reed is split into two sections so that the primary contacts do not share a common earth with those of the secondary. This allows a negative bias supply to be obtained by earthing the secondary reed through a back-bias resistor.

Synchronous vibrators were preferred for domestic radios because the inefficiencies of a thermionic rectifier were eliminated – an important consideration when the battery has to be charged off-site.

Old is new again

It is no coincidence that when presented in a purely solid-state form, the circuits described closely resemble a modern switchmode power supply. All modern DC-DC converters use the same principles. However, instead of a mechanical contact interrupting the DC input, a bipolar transistor, Mosfet or IGBT is used. Likewise, because of the inductive load, steps have to be taken to prevent destructive voltages appearing across the switching device.

In modern switchmode supplies, rectification of the secondary voltage is usually taken care of by silicon diodes. In synchronous switchmode supplies, the rectification is taken care of by Mosfets or IGBTs which are "synchronised" with the input switching devices.

Of course, input and output filtering is still required, just as in the mechanical vibrator supplies, to prevent radiation of RFI. The only fundamental difference in operation is that the vibrator supply is operating with a fixed duty cycle and is therefore unregulated.

Vibrator faults

After many years of disuse, an insulating film builds up on the contacts. Some literature describes it as due to oxidisation of the contact metal but my observation is that it could also be a decomposition by-product (one source suggests sulphur) released from the sponge rubber that's used to line the inside of the can.

Because of this film, the most usual result when powering up a long-disused vibrator is that, if it's a series-drive type, it will vibrate but produce no output or only a half-wave output. Alternatively, if it's a shunt-drive type, it won't start at all. Even NOS (new

Further Reading

Silicon Chip:

(1) January 2001 – Operatic Mignon 32V Mantel Radio.
(2) November 2002 – AWA 532MF 32V Mantel Radio.
(3) September 2003 – Vibrators Pt.1
(4) October 2003 – Vibrators Pt.2.
(5) March 2005 – Astor AJS Car Radio.
(6) June 2008 – DC to AC Inverters Pt.1.
(7) February 2008 – DC to AC Inverters Pt.2.
(8) May 2015 – AWA 523-M 6V Mantel Radio.

Radio & Hobbies, September, October & November 1944: A Study Of Vibrator Power Supplies.

Electronics Australia, October 1975: Solid-State Vibrator Circuit.

old stock) vibrators straight out of the box can exhibit this sort of behaviour.

At this point, most restorers remove the can to clean the contacts. With the Oak type, this is easily done; it's just a matter of removing a spring clip at the base and desoldering an earth tag. Unfortunately, it's impossible to open crimped-can types without some disfigurement.

Cleaning the contacts

Often though, it isn't necessary to open the can to clean the contacts. For many years now, I've applied a high voltage to the contacts to break down and burn off the film. This method requires a 240VAC isolating transformer and a 100W incandescent light bulb, connected as shown in Fig.4. A battery or DC power supply is also required to drive the reed.

WARNING: to ensure your safety, you MUST USE an isolating transformer (see Fig.4) and no connections or parts of the vibrator or DC supply should be touched while power is applied. The transformer isolates the vibrator and the external DC power supply from the mains and also ensures that if the DC supply's output is earthed, then the mains will not be shorted to Earth (ie, the transformer is NOT an optional extra). Finally, DO NOT carry out this procedure unless you know exactly what you are doing.

For a series type vibrator, with the driving coil powered up, the reed should start vibrating and the current drain will only be a few hundred milliamps. Next, 230VAC is applied to each contact in turn, via the 100W lamp from the isolated supply. The lamp limits the current when the film burns off and the contacts start working, and provides a visual indication that the process has been successful.

Once the contacts are functional, the light bulb will appear to flicker at a slow rate, because of the difference between the vibrator and mains frequencies.

If the reed won't vibrate, the can will have to be opened for further examination. The usual cause of the problem is a broken solenoid wire or the contact screw might need adjustment.

Shunt-drive vibrators require a different set-up. In this case, I use a 30V bench supply, current-limited to 500mA, to try to get the reed vibrating (ie, before high voltage is applied to the other contacts). Applying the current to the coil will force the reed to swing over to the contacts. By rapidly making and breaking the 30V connection, the driving coil will develop a high-voltage back-EMF which is enough to break down the film. It can take quite a few minutes before it breaks down but this procedure is preferable to opening a crimped can.

It is also sometimes possible to force the reed to vibrate using another 100W bulb instead of the 30V power supply but only if the reed frequency is a harmonic of 50Hz.

Once the contacts function, the vibrator will start. Obviously, the power supply must be current limited as it is short circuited when the contacts make. With the vibrator buzzing, the other contacts can then be cleaned with high voltage as previously described. Incidentally, the driving coil for shunt-driven vibrators normally operates at twice the supply voltage because of transformer action, so the application of 30V for a short period is not harmful.

Do not fall into the trap of a vibrator operating in a half-wave mode. Just because it buzzes and produces an output, all may not be well. Symptoms of half-wave operation include a low output voltage and arcing in one set of contacts.

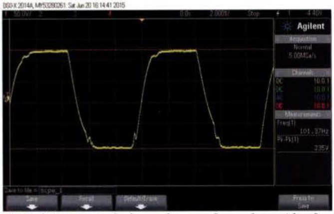


Fig.5: this scope grab shows the waveform of one side of the power transformer secondary in the AWA 946AZ car radio. Note that the input to the scope was attenuated 2:1, so the actual voltage is twice that shown.

Fig.6: this waveform shows the output of a Cornell Dubilier 12V DC to 115VAC 60Hz inverter.

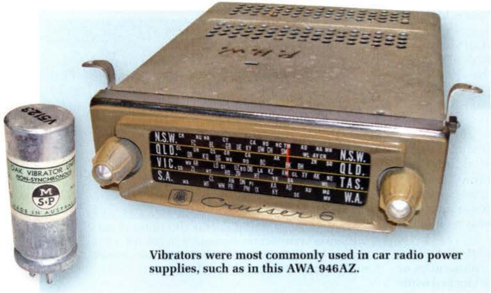
This occurs when the other set of contacts is not functioning; often because of a dry joint or because the vibrator socket is faulty. The output waveform will be asymmetrical. The trap here is that the radio will work in this condition but the user will be oblivious to the damage occurring to the contacts.

Contact adjustment

The contact spacing adjustment is a compromise between output voltage and the possibility of sticking. The less "dead time" (and thus spacing) there is between one set of contacts opening and the other closing, the higher the output voltage. Conversely, if they are too close together, contact sticking can become a problem.

If the output voltage is low and the other components are known to be OK, chances are the contact spacing needs to be readjusted. In the case of synchronous types, the secondary contacts are set to close just after the primary contacts and to open just before them. This eliminates the arcing that would otherwise occur because at these times, the voltage across the contacts is at a minimum.

Makeshift contact adjustments can be done by measuring the transformer secondary voltage and adjusting the primary contacts to bring this up to specification. Likewise, the secondary contacts can be adjusted to produce



Vibrators were most commonly used in car radio power supplies, such as in this AWA 946AZ.

the maximum B+ voltage without any sparking.

A crude method that can be used to set dual interrupter contacts is to temporarily reduce the buffer capacitance enough to just make the contacts arc. The first set of contacts is then set as per a non-synchronous type, while the second set of contacts is set so that they arc by the same amount as the first.

That said, an oscilloscope is really essential for proper vibrator adjustment because it reveals the contact condition, timing and operating conditions in a manner that meters and visual inspection cannot.

Can lining

If you have to replace the foam rubber can lining, it's important for the actual vibrator assembly to be allowed to "float". Having it held tightly changes the operating conditions – clearly visible on a scope. Early vibrators use a loose wrapping of felt and this is a satisfactory alternative if suitable rubber material cannot be obtained.

Transformer problems

If one half of the transformer's secondary has gone open circuit, the good half can still be used by using a bridge rectifier to replace the existing rectifier valve or the vibrator's secondary contacts (if fitted). The buffer capacitor must, of course, be connected across the good half but note that unless there was originally only one buffer capacitor across one half of the winding, its value has to be increased.

If the transformer has failed completely, a common 240VAC power transformer can be used as a replacement. Some types work better than others but by far the best type to use is a toroid.

In this case, because the primary (240VAC) winding isn't centre-tapped, a bridge rectifier must be used. In addition, because the duty cycle will be less than 100%, the turns ratio needs to be higher than first thought. For example, a 9-0-9V low-voltage winding is required to provide a 240VAC output from a 12V supply.

If the transformer is changed, the buffer capacitor may need to also be changed. In fact, it must usually be increased if a 50Hz transformer is used.

The ideal buffer capacitor is one that results in minimum primary current, together with an output waveform that has no overshoot on the rising edge or excessive slope on the trailing edge. Nor must there be any contact arcing. The operation of the buffer capacitor should be checked with the vibrator in its can, as there can be a slight change in duty cycle and frequency after it is enclosed.

Substituting vibrators

If a synchronous or dual-interrupter vibrator is being used to replace a non-synchronous type, it's a good idea to parallel the unused contacts with the existing primary contacts. Conversely, substituting a non-synchronous vibrator in place of a synchronous type can only be done if a valve or solid-state (diode) rectifier is used to replace the secondary contacts.

Note also that a low-voltage series-driven vibrator can be used in a higher-voltage circuit provided a resistor is installed in series with the driving coil. For example, you can use a 27Ω 5W resistor for 6V Oak vibrators operating from a 12V DC supply.

Finally, if the new vibrator operates at a different frequency, the buffer capacitance needs to be checked. Also, if the vibrator is mounted horizontally and is substituted with a different type, ensure that the reed is in the vertical plane, otherwise there might be gravitational bias towards one set of contacts.

High efficiency

Many restorers have fallen into the trap of assuming a vibrator is merely a buzzer converting DC to AC. This leads to frustration and ultimately the installation of an electronic replacement.

In fact, the electromechanical vibrator is a precision component with extensive research and development behind its design. Because a vibrator is an on/off switch with minimal voltage drop, the efficiency of a well-designed circuit is high (the inverter in Fig.1 has an efficiency of 83% with a 40W load). In fact, most of the power loss is from the transformer, driving coil and damping resistors – not the vibrating contacts.

Because everything from the regulation of the vehicle's charging system to the circuit design affects vibrator life, manufacturers don't usually specify what this is. So just what kind of life can we expect?

Well, various 1930s sources do make such claims as "5000 hours" or "four times the life of the rectifier tube in the set". Having collected nearly 100 vibrator-powered items over the last 35 years, I have never had to replace a vibrator unless it was missing to begin with. Some of my radios and inverters have been in daily or weekly use for the last 10 years (powered from a 12V solar supply) and all have operated without fault.

It's interesting to note that AWA was still producing a vibrator-powered car radio (the 946AZ) as late as 1965, as shown in the accompanying photo. The reliability of the Oak vibrator and AWA's attention to design detail ensured that this radio was competitive with its transistor counterparts of the era. Indeed, many of these radios operated without fault well into the late 1980s.

Clearly, when understood and operated correctly, vibrators can be just as reliable as other components. **SC**