

## Vibrators and vibrator receivers - 1

There are many vibrator powered radios that find their way into swap meets and auction marts. There is a very good reason why they are still to be found in such numbers: they were very practical, for many years...

T HAS BEEN mentioned here before that reticulated 240V AC power did not extend beyond the cities and the major country towns of Australia until about the middle 1960s. By implication, until then most farmers had to rely upon other sources of power — notably the 32V home lighting plant and the 6V vibrator powered radio.

Although radios were produced for 32V DC, six volt vibrator-powered radios were far and away the more numerous, and were really only superseded by the advent of reticulated electricity and the emergence of the new cheaper Japanese transistor radio, which made the purchase of a new accumulator or the repair of the faithful old set uneconomical.

#### Why 6V, and vibrators?

Firstly, now is as good a time as any to lay to rest an unfortunate misconception. The term 'vibrator' was a wholesome and proper part of a radio man's terminology and was freely discussed by Catholic and Protestant radio men alike. There was no hint of unseemliness. In this context a vibrator is an electromechanical device, which when used with an appropriately designed transformer, formed either a DC to DC converter or a DC to square wave inverter. The former were referred to as a 'synchronous type' vibrator, while the latter were the 'non-synchronous type'. As a rule for radio work, the synchronous types supplied 130V DC or so from a 6V accumulator, as a substitute for the expensive B batteries.

Six-volt accumulators were chosen for three good reasons. Firstly, most cars up to the FJ Holden, in addition to farm machinery, used a 6V system. Charging the battery was merely a case of swapping the radio battery over with the car battery, and by the time the 'cocky' had made a couple of trips to town, the battery was charged.

Secondly, in the case of the 2.0V series of valves, it was possible to design a very convenient series-parallel network for supplying the valve filaments. And thirdly, in the case of car radios, the same valves which were used

in electric sets were likewise used because of the convenience of a 6.0V heater supply.

In an all-battery powered radio, a bank of three 45V dry batteries would last from four to six months, depending on current drain and hours of use, while the 2V accumulator lasted about 6-8 weeks. Vibrators eliminated the need for costly dry B batteries, and changing to 6V avoided the need for special charging arrangements for the 2V accumulator.

The one drawback was that the 6V accumulator only lasted only two to three weeks between charging. However, as we have seen, charging the radio battery was essentially at no cost, to the enterprising farmer!

#### The basic principle

Now let's have a look at the way vibrators work. Fig.1(a) shows the circuit of a common electric bell or buzzer. The make-andbreak action of the buzzer spring (hereafter called the 'reed') and the adjusting screw, causes a pulsating or interrupted DC to flow through the armature coil.



Fig.1: In (a) we see the principle of an electromechanical buzzer, where an electromagnet interrupts its own current. In (b) we see how a vibrator is essentially just the buzzer in a different physical form, while (c) shows the first practical attempt at using a half-wave non-synchronous vibrator to generate the HT in early auto receivers.

### •••••••••••••••• by Roger Johnson



Fig.2: A closeup of a vibrator cartridge removed from its protective shielding can. The array of adjustments is quite complex, to be discussed next time.

If a secondary winding was wound around the armature coil, a voltage would be induced in the secondary as a result of the collapsing magnetic field when the reed was in the 'break' or 'off' period of the cycle. The frequency of the vibrating reed could be determined by the adjusting screw.

The vibrator cartridge is simply a more sophisticated and elaborate development of this simple buzzer principle.

Fig.1(b) shows a modified arrangement. This time the armature coil is at the free end of the reed, so that the reed can more easily oscillate, and with a greater amplitude. Not only that, the primary contact has a certain resilience. This means that it can accommodate variations of the amplitude of the reed vibration, so that the 'gap' remains more constant. This is important for reasons that will become apparent soon. The system of Fig.1(b) also allows the addition of extra contact points.

As you can see, Fig.1(b) is simply a rearrangement of Fig.1(a). The chief advantage is that it permits additional flexibly mounted contacts on each side of the vibrating reed. These in turn can control other electrical circuits, independent of the driving armature coil.

This is indeed what happens in a vibrator cartridge. The close-up photo in Fig.2 shows a complicated array of contacts as used in a synchronous, or rectifying, cartridge.

Like the ignition points in a car engine, the contacts of a vibrator cartridge open and close literally millions of times during their service life. A vibrator cartridge operating at 115Hz will have over one million contact movements every 2-1/2 hours. Special electrical and mechanical engineering must be undertaken if any sort of longevity is to be anticipated. The engineers of the day aimed at 1500 to 2000 hours of operation.

#### The early attempts

The development of the ultimate 'modern' vibrator cartridge came as a result of the demand for automobile receivers in the early 1930s. In this instance, the vibrators were used as shown in Fig.1(c). Until then, what car radios there were had to be supplied by separate HT or 'B' batteries (see, for example, Vintage Radio in *Electronics Australia* for June 1998).

These early attempts comprised a single



adjustable resilient contact, in which the energising coil was in series with the primary of the transformer. Half-wave rectification only was possible, and was achieved using a conventional valve.

Since the armature or magnetising (interchangeable words) coil was in series with the transformer primary, this meant that the total primary current was drawn through the armature coil. It therefore had to be of a very low DC resistance. Not only that, the DC resistance of the transformer, and the imbalance of the reflected load during operation, meant that the operation of the reed could easily be disturbed unless the load conditions, transformer primary and armature coil were carefully designed, matched and maintained.

Furthermore, if the 'points' (synonymous with 'contacts') became in any way pitted of corroded, there was an excellent chance that the reed would not commence vibrations at all. This is a classic example of a case where 'giving it a slight whack' may have fixed the problem, by jolting the reed into operation! Following on from this was an even worse contraption designed to eliminate the rectifier valve. A second set of contacts was placed on the reed — electrically quite separate from the primaries of course — to enable rectification. This model developed the same faults as the early non-synchronous type of Fig.1(c), but with worse results. The secondary contacts tended to arc and pit even more so than the primary contacts.

Fuses and secondary delay relays were sometimes incorporated to give the secondary contacts that fraction of a second delay, in order to get the reed moving before the load was placed through the secondary contacts.

#### **Parallel coil vibrators**

A big improvement came with the full wave parallel coil vibrator, of the type seen in Fig.3(a) — which happens to be a synchronous (i.e. rectifying) type. This is the type in common use from about 1936 until the end of the vibrator-powered car radio (1958 or thereabouts) and many a receiver was kept in service until the mid 1960s. Not only that, they were extensively used in military receivers (in particular in WW2) where much development took place in insulating, moisture proofing, sound proofing, and most important of all, providing reliable contacts.

With this type of vibrator the armature coil is wound with many turns of fine wire



Fig.3: In (a) is shown the basic circuit for a synchronous (rectifying) vibrator supply, while (b) shows that for a non-synchronous vibrator, where a rectifier valve must be used. In (c) is shown how the uncommon split-reed synchronous vibrator was used. Representative vibrator cartridge base connections are also shown, for reference.

to give a much higher DC resistance, suitable for parallel connection with one side of the low resistance DC winding of the transformer primary. The magnetic energy was provided by the large number of turns, with a small current flowing. It will be seen that the contacts are open when the reed is at rest, and that the armature coil is energised via one lead going directly to one side of the DC source (negative), and the other via one half of the transformer primary.

Because of the higher voltage/low current operation, the problems with contact resistance was virtually eliminated together with starting difficulties.

At switch off, the reed is neutral to all contacts. Immediately a voltage is applied, the armature coil is energised in the manner described above, and when the reed moves to the bottom contact, it shorts out the armature coil. This has two effects, one being that the bottom half of the transformer is now connected to the DC source. So the magnet is effectively switched off, and contact is broken. The spring inertia of the reed moves over to the top contact.

Once the bottom contact is broken, the top half of the transformer primary is still disconnected from its DC source, until connection is made with the top points. As a result of the magnet coil releasing the reed and energising the top half of the primary, the reed in the process of disconnecting itself from the bottom contact allows the armature to be energised again and the armature draws the reed down to the bottom points; thus the whole process is repeated whilst the primary voltage is connected.

Under these conditions, contact is made alternatively between the reed and the two 'primary' points (contacts), and pulses of DC pass through the respective halves of the transformer winding in opposite directions.

The frequency of vibration is governed by the characteristic of the reed and the pull of the magnetic circuit. Usually, a frequency of between 115Hz and 120Hz is the standard.

The schematic of a vibrator circuit found in many circuits for a full wave non-synchronous (i.e., non rectifying) is shown in Fig.3(b).

#### Synchronous types

The big advantage of synchronous or rectifying vibrators was elimination of the rectifier tube, thus saving its cost and also eliminating 0.6A of current drain from the accumulator. In a car radio, where the car's accumulator is constantly being charged, this does not pose a problem. However, for a domestic radio, whose drain depends on the number of valves and total HT current, the extra 0.6A becomes quite significant and can shorten battery life by as much as one third.

Returning to Fig.3(a), the secondaries of the transformer are connected by the contacts to the reed, which is always at negative (ground) potential. Assume that at a given instant, the reed is touching the lower primary contact. With the polarities as marked, the lower end of the primary will be negative with respect to the centre tap. If the transformer secondaries are correctly phased, the lower end of the secondary will simultaneously be negative for the high tension. The secondary centre tap is therefore positive.

When the reed travels to the top set of contacts, the same thing happens. The reed is at earth, the top of the secondary winding is negative and the centre tap is therefore positive HT.

Because LT negative is common with HT negative, with the standard synchronous vibrator, there can be no attempt at supplying back bias. However, a 'split reed' vibrator cartridge was developed, with a secondary reed. This was mechanically coupled to, but electrically isolated from the primary reed, as shown in Fig.3(c), and this did allow for the provision of back bias. However, circuits and applications for these split reed cartridges are uncommon; the vast majority of domestic radios used a six-pin 'Oak' or five-pin 'Ferrocart' (made by Astor) synchronous vibrator.

Vibrators and their associated transformers were designed for 4V, 6V, 12V and 32V operation. 32 volt jobs were for home lighting plants, whilst the vast majority of domestic radios used the 6V type — with the principal exception of AWA who, for two or three years, preferred 4V types. The 12 volt types were used for car radios with 12V systems, and were mostly non-synchronous.

In closing, I should mention that the schematics of Fig.3 only illustrate the basic concepts of vibrator operation. No mention has been made as yet of filtering and associated circuitry. We'll look at these aspects in the near future.



# Vibrator Power Supplies — 2

Last month we discussed the general principles of vibrator cartridges and the way they work. This month we look at the peripheral circuitry and how to put theory into practice.

ERELY CONNECTING a vibrator, accumulator and transformer together and hoping for the 130-odd volts DC sufficient to operate a valve radio is a far cry from reality, as it happens. The circuit for a vibrator power supply is shown in Fig.1, and as you can see there's quite a bit more to it.

There are some basic design considerations to bear in mind. Firstly, the final output voltage is basically determined by the turns ratio of the transformer, not the vibrator cartridge. A given cartridge can work almost any vibrator transformer for a determined voltage, within certain limits.

Secondly, there needs to be filtering in both the primary and secondary circuits, as you can see. This cannot be over emphasised, because a vibrator power supply is essentially a switch-mode system — and using mechanical switching contacts, so without filtering it generates huge amounts of RF interference.

The third consideration is whether the supply is to use a valve rectifier, or a synchronous vibrator (as shown in Fig.1) which provides its own rectification for the secondary side.

By the way for most purposes you can regard a vibrator power supply as a substitute for HT batteries, for radios which normally would have used a bank of three 45V dry batteries in series.

#### In more detail

Like an ordinary mains transformer, the entire load of a vibrator transformer is ultimately transformed into the current and voltage drawn through the primary. In the majority of cases the primary voltage was 6V, so the HT loading becomes transformed into a certain current at this voltage.

Let's assume a typical five-valve receiver consisting of an RF amp, mixer, IF amp, detector/audio and output. Such a set operating under maximum conditions could easily draw 20mA from the HT supply (say 135V). For dry battery operation, screen



Fig.1: A typical vibrator power supply using a synchronous or self-rectifying vibrator cartridge. This is the complete circuit showing the shielding of the battery leads. The numbers refer to the base connections of a typical cartridge.

voltages and grid bias would ensure that this figure would be kept down to about 14mA for the sake of battery economy. Therefore, the secondary load is 2.7 watts.

Given a transformer efficiency of 80%, the transformed secondary loading becomes 3.375VA in the primary circuit. As the primary voltage is 6V, the primary current is therefore 0.5625 amp.



Fig.3: Underneath the sub-chassis of a typical vibrator power supply.

Now the vibrator cartridge itself is only about 75% efficient at best, which means that an average of about 0.75A will flow through the primary contact points, to satisfy the set's HT requirements.

Of course the valve's heaters must also be powered, and the ubiquitous 1D4/1L5-G output valve drew 0.24A. The remaining four valves were most often types chosen that drew 0.12A, so that they neatly formed a series-parallel network which provided each valve with its correct voltage and current requirements when it was connected across a 6V accumulator.

Hence the total current supplied by the accumulator would be very close to 1.0A (0.75 plus 0.24).

In theory, a 160AH (ampere-hour) accumulator would provide 160 hours of operation at this drain, although it seldom was able to do so for radio work. Basically, listening to the radio for about five hours per day would give three weeks or so life from the accumulator, while seven to eight hours per day reduced that figure to a fortnight. These figures seem to match the anecdotes provided by the old timers who used these sets.

#### The transformer

The transformer used for vibrator supplies was typically designed with a liberal amount of iron and plenty of turns-per-volt, to ensure that the core did not approach saturation, even with a rise in primary voltage, such as may happen with an automobile radio. (The voltage across a 6V accumulator may rise to as much as 8V under full charge, particularly with some of the primitive regulating systems on the older cars.) Such provision minimises magnetising current and makes for greater efficiency. The transformer efficiency quoted above may therefore be a little conservative.

#### The vibrator itself

This is where the designers' persistence paid dividends, because when properly adjusted and initially set up, vibrators were designed for something like 1500 to 2000 hours of service life, about the equivalent of a radio valve. However, unlike a radio valve, a vibrator cartridge is repairable.

Of course if the magnet (or armature) coil is burnt out, there is little that can be done. 'Ferrocart' cartridges designed for 32V home lighting plants were said to have given trouble in this regard.

There are five adjustments on most standard 6V volt synchronous vibrators. Firstly, there is the adjusting screw and locknut shown on the framework in Fig.2 last month. This adjustment sets the frequency of vibration of the reed, and can have a bearing on the output voltage.

Also shown in the same photo are two pairs of contacts. In the photo as shown, these are the primary contacts. Directly behind these, and obscured by the primary contacts in the photo, are the secondary contacts.

#### The 'points'

The condition of the contacts is vital if 'hash' is to be eliminated and correct excitation at switch-on is to occur. In this instance they are like the 'points' in the older type of ignition system used in cars. If the points are pitted, the car is hard to start and will misfire



Fig.4: A complete mantel radio chassis using a vibrator supply for HT. Most of the vibrator supply components are in the big metal box on the right.

under load, particularly when the ignition timing is advanced by the vacuum advance.

The points in a vibrator cartridge must therefore be as clean and flat as possible, with the contact surfaces as parallel as possible, and the gaps for the primary contacts as equal as possible.

The gaps for the primary and secondary contacts of a synchronous vibrator are different, by the way. The primary contacts are spaced a little closer together than the secondaries. Thus the secondaries close after, and open before, the corresponding primary contacts. This is done so that when the primaries close, there is only the magnetising and core saturating current that initially passes through the contacts, which is much less than the 0.75A that passes through the primary contacts under full load.

In other words, the primaries are closed before full load is applied, and opened after full load has been removed. This markedly reduces the tendency to primary arcing.

When the secondary contacts are closed, the input filter capacitor is almost fully charged to the voltage which appears across the particular half-secondary winding. This charged capacitor is vital to maintain the potential as nearly as possible across each of the contacts, and as we shall see, reduces the tendency of the secondary contacts to arc or spark.

While the reed swings across and closes the other secondary contacts (the opposite primaries having closed first under no-load conditions), the charged filter capacitor maintains the secondary potential at the secondary centre tap.

We must remember that much the same as an ordinary mains transformer, the ends of the secondaries are opposite in polarity to the centre tap. With a properly designed filter system with adequate capacitance, the HT input filter discharges only fractionally during the entire cycle. This means that the respective ends of the half-secondaries are at zero potential, or very nearly so, at the instant just before secondary contact closure. As a result the potential difference between the secondary contacts and the reed is also



very nearly zero, resulting in minimal sparking across the secondary points.

#### The 'buffer' capacitors

The buffer or timing capacitors are those shown connected between the ends of the secondary. In some circuits, each capacitor is connected between one end of the secondary and the centre tap, or only one capacitor is used, connected across the entire secondary. Occasionally, series resistors of between 50 and 100 ohms are placed between the transformer secondary ends and the buffer capacitors, and a larger value capacitor (20 to 50 times the value) is placed directly across the primary.

The functioning of the buffer capacitors is quite complex, and is described by the older texts as follows:

When one of the set of primary contacts is closed, the battery is connected across that respective half-primary. The resultant current flow in the primary is opposed by the so-called 'counter EMF', which builds up to a certain value during the brief interval that the contacts are closed. When the contacts open, the field collapses, and a voltage builds up in opposite polarity to the original counter EMF.

In a no-load position, i.e., when the reed is oscillating between the contacts, the building up and collapsing of the magnetic field may in fact repeat itself and caused damped oscillations within the transformer. This can cause interference of its own accord, but more importantly, a situation can arise when a portion of the damped oscillation is opposite in polarity to the applied voltage when the contacts close, thus causing serious sparking, and greatly reducing the service life of the contacts.

The situation can be corrected by placing the buffer capacitors in place as already described. The effect of these capacitors is to cause the transformer to resonate at the same frequency as the mechanical frequency of the vibrating reed. When properly adjusted, the induced EMF has reversed in polarity again, and is approaching the terminal voltage of the battery when the points close.

Variations in transformer characteristics, vibrator characteristics, primary and secondary voltages and loading can all affect the electrical resonance, and the values of buffer capacitors are best determined at the workbench with the aid of a CRO to study the waveforms. The unsuppressed spikes can reach quite high voltages, and ordinary paper capacitors are not recommended. Mica types of 1nF or 2nF value and 1000V rating were preferred.

#### Low tension filtering

The continual make and break action of the points (carrying 0.75A) fractionally lowers the battery voltage when the points are closed. Hence the voltage measured at the battery terminals is fluctuating at the vibrator frequency. This causes ripple to appear at the valve filaments, and can greatly exacerbate hum just like an electric set with poor filtering. Consequently, both air- and ironcored chokes of very low DC resistance were used for filtering, together with capacitors as shown.

One, and sometimes two air-cored chokes (marked 'AFC' in Fig.1) were placed in series with the primary, and at least one iron-cored choke was placed in series with the valve heaters as shown, with a 500uF filter capacitor for further smoothing. Shielding the battery leads, down to but not including the negative battery clip, reduced the tendency for radiation of RF hash — which could otherwise be picked up by the antenna.

The DC resistance of these filter chokes must be of necessity a no more than an ohm

Fig.2: The vibrator circuit of a Healing 408A receiver. Only the socket connections are shown in this case. The buffer capacitor is the 0.5uF unit connected across the primary, and also the two 10nF units in series across the secondary.

or two in total. Even one ohm will cause a voltage drop of 0.75V, which is enough to drop the primary voltage to 5.25 volts and reduce the secondary voltage by perhaps 15V. A resistance of one ohm in the leads to the filaments will produce a voltage drop of 0.25V, which is tolerable.

#### **HT filtering**

In Fig.1 you can see that there is also an RF choke in series with the HT output from the transformer secondary centre-tap. The vibrator and transformer are an excellent source of RF hash, but by careful design it can be almost eliminated.

The buffer capacitors may reduce the sparking, but do not completely eliminate it. Also, pitting and corrosion of the points due to maladjustment or normal wear-and-tear can and will cause sparking. Not only that, the buffer capacitors do not completely eliminate damped oscillations, and even though sparking across the points may not have occurred, plenty of interference can make its way to the high tension output. The RF choke and a couple of bypass capacitors of 1 or 10nF are necessary to provide adequate filtering.

The DC output from a vibrator supply is like the unfiltered output from a valve rectifier, except that the waveform is of a different shape. Instead of being a succession of adjoining positive portions of sine waves, the output waveform from a vibrator is a succession of square waves. If both sides of the transformer were identical in every respect, and also the gapping of the points, the output might be continuous. In reality, there is likely to be transient negative 'dips' from Vmax to zero, as well as fluctuations in Vmax according to minor differences in the constants described above.

The normal filter circuit of two 10uF electrolytics and an iron-cored choke of 10 or 12 henries is designed to eliminate any HT ripple at the fundamental conversion frequency.

As you can see, another important element in containing the RF hash generated by a vibrator supply was to enclose the vibrator, transformer and RF filtering components in a metal shield box.

This and last month's columns have described how a vibrator works. Next time we'll look at repairs to vibrators and vibrator powered receivers in general.  $\diamondsuit$