

Solid State Pulse Counting FM Receiver.

While the [valve pulse counting FM receivers](#) presented elsewhere on this site work very well, there was still a need for a solid state version. I envisaged such a set might be used as a small portable battery powered receiver, allowing good quality FM reception without the problems of special parts and the multiple tuned circuits required for conventional superhets.

Most constructors these days just use a TDA7000 IC for home made FM receivers. It works very well, but in a way it is cheating as it's really a case of RF in, audio out, with a few minor components. It also requires a carefully designed printed circuit board.

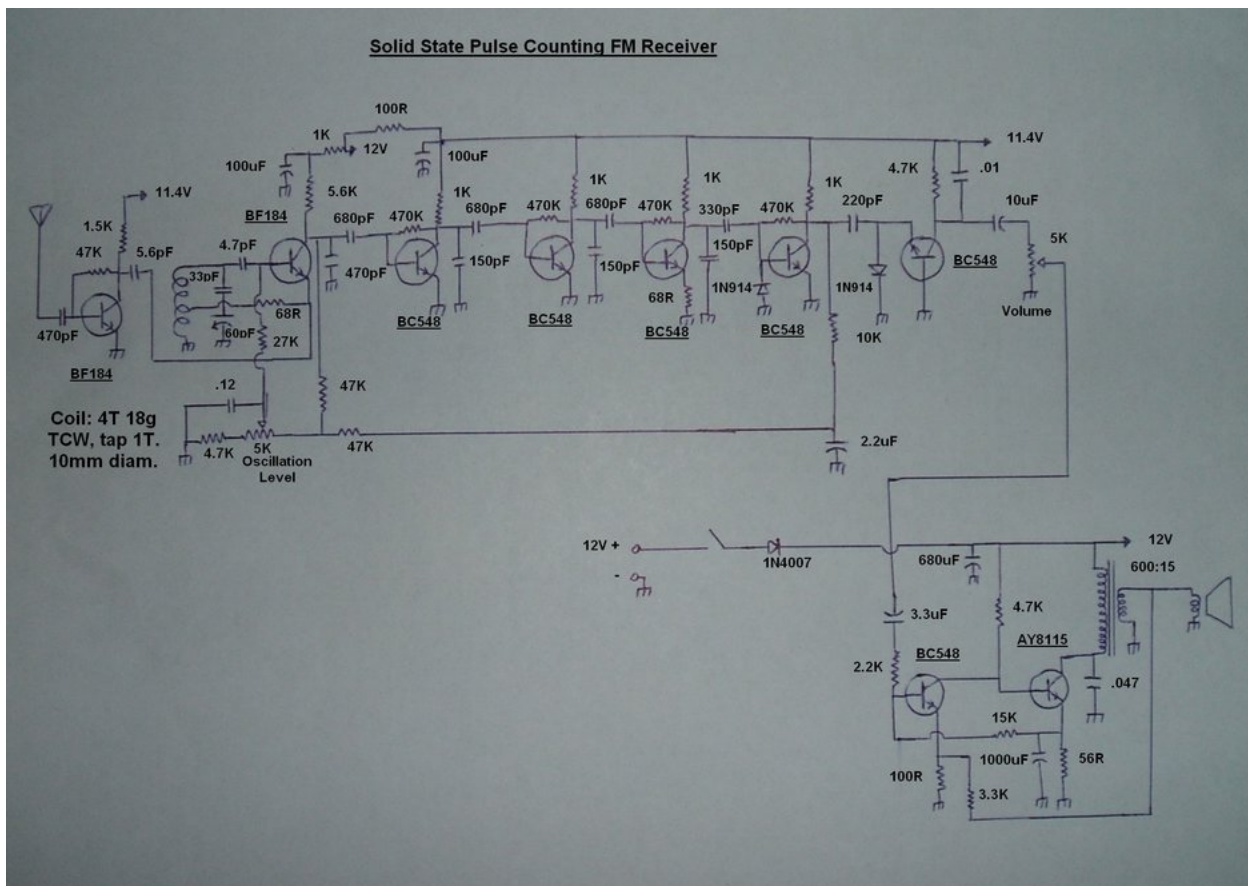
The challenge here was to make a proper FM receiver with all discreet components, and like the valve sets, have only one tuned circuit.

This has been a long term project which I started back in the 1990's and revisited a few times over the years. While there was no difficulty in getting the excellent sound quality, the problems were caused by a very critical and insensitive frequency converter stage. As always, the valve circuits just performed better.

In 2011, I made a considerable improvement with the design and it was "almost good enough". Now, in 2016, that design has been improved further and the receiver is quite practical for everyday use with no critical controls.

Designs for solid state pulse counting receivers have existed since the 1960's, but like their valve counterparts have never been widely publicised. Again, the technique was mainly confined to the UK and Europe for home constructed sets. The solid state designs follow the same basic design; a frequency converter producing a 200 kHz IF which is then amplified using resistance coupled amplifiers. This is limited (clipped into a square wave), and then differentiated before driving a pulse counting or tachometer circuit, which then provides the demodulated audio.

The Circuit.



RF Amplifier.

This is a very simple stage which is the same as initially used with the [6 transistor super-regenerative receiver](#). As can be seen, it is untuned for simplicity and has little gain. Its main purpose is to isolate the aerial from the following converter stage. If not isolated, loading effects will affect the operation of the converter and can stop it working altogether. Here, a BF184 operates as a self biased resistance coupled amplifier. The low collector load ensures some gain at VHF, although not as much as if the circuit was tuned. The input is isolated by a 470pF capacitor which functions as a simple high pass filter. It also prevents the bias being short circuited if the aerial has DC continuity, such as with a folded dipole, or where a balun exists.

Frequency Converter.

This, more than anything else was the real challenge. I tried several types of configuration here using both silicon and germanium transistors, along the lines of the various magazine projects shown further down. While they all could be made to work, the operating conditions seemed excessively critical, and sensitivity was quite poor, with 100uV typically needed for quiet reception. The idea of separate oscillator and mixer stages was considered, but it would be getting away from the simple design of an autodyne converter. Then I looked at the 6 transistor super-regenerative receiver circuit and its detector stage. This had particularly good stability and non critical adjustment, so it would appear to hold promise as an autodyne frequency converter. With suitable modifications made; mainly by substituting a fixed voltage for the original sawtooth quench voltage, it did indeed work quite well. Another BF184 is used as a Hartley oscillator. If tuned so its oscillation frequency is 200 kHz away from the station carrier, then present at the collector is a 200 kHz IF. The VHF signal present is bypassed to earth by the 470pF, also connected to the collector. Importantly, the 470pF is not enough to bypass the 200 kHz IF, so this passes through to the first IF amplifier. The incoming RF signal is fed into the emitter, as tapped lower down the oscillator coil, the loading effects of the RF amplifier are reduced. Base bias is via the 27K resistor, fed from a 5K pot. Initially, the 5K pot was fed with a regulated 1.4V supply. Because of the critical bias setting, two series connected diodes were used in a shunt circuit to produce this 1.4V. Without this, any supply voltage variation would have a serious effect. Because of changes in oscillator performance from one end of the band to the other, it was necessary to readjust the bias control as the receiver was tuned, if maximum sensitivity was to be obtained.

A big improvement was had by rearranging the bias supply in a DC feedback circuit. Now, the bias comes from the collector voltage via the 47K resistor. If the transistor draws more current, the collector voltage falls, and then so does the bias. This reduction in bias then allows the collector voltage to rise again and offset this. It is a standard bias stabilising configuration used in many transistor circuits. Using a spectrum analyser, it could be seen that the amplitude of the oscillation was much

more constant across the band, and for all practical purposes the oscillation level control only needed to be set once at the low frequency end of the band. The final improvement was an AFC circuit, which will be discussed later. The tuning capacitor used is the 60pF oscillator section of a modern plastic AM radio type. The 160pF aerial section is not used, but could be if an AM tuner was also incorporated. The series 33pF limits the tuning range. Ideally, a single 15pF tuning capacitor would be used, but these are not as common. It should be pointed out that using a series capacitor with a larger than desirable tuning capacitor does cause the tuning adjustment to be non linear. The effect is that the higher frequency stations are closer together than those at the low frequency end of the band.

IF Amplifiers.

Here I experimented with several circuits which were really all much the same except for component values. The one I settled on was taken from a dual conversion circuit from the internet. It actually appeared to be properly designed for the required frequency response.

Each stage is the same, based on a BC548 transistor, and there are three such stages. High frequency roll off is provided by the 150pF capacitors between collector and earth on each stage. Low frequency roll off is conversely provided by the 680pF base coupling capacitors. The third IF amplifier includes a 68R emitter resistor for stability.

No doubt, one could use an op-amp if one wanted to get away from the discreet component design.

Limiter.

The amplified 200 kHz FM signal needs to be squared up prior to feeding the detector stage. This is done with the fourth BC548 which operates with an inverse connected diode between base and earth, clipping the negative peaks. Likewise, the positive peaks are clipped by the base-emitter junction of the transistor. Provided the signal strength is sufficient, the voltage here will be strong enough to drive both diode junctions into conduction.

Detector.

The clipped 200 kHz FM signal is now differentiated with a 220pF capacitor. This feeds another diode-transistor circuit which is where the so called "pulse counting" takes place. Imagine the base-emitter junction of the fifth BC548 is a diode. It can be seen that when a positive pulse is received that the 1N914 conducts and charges the 220pF. The BC548 base-emitter junction is reverse biased and no collector current flows. When the pulse goes negative, the 1N914 is reverse biased, but the base-emitter junction is now forward biased by the discharging 220pF, and collector current flows causing the collector voltage to fall.

Note the .01uF capacitor in parallel with the 4.7K collector load. This averages out, or filters, the pulses present at the collector. Now imagine what happens when this circuit is presented with FM.

If the frequency is low, the pulses are further apart. Therefore the average collector current is low. When the frequency is high, the pulses are closer together, effectively present for more time. So, average collector current is increased. In this way, the voltage across the 4.7K/.01uF varies at the same rate as the pulse repetition. The result is the original audio signal.

Audio Amplifier.

This is a circuit configuration I have used for many years in many projects. Not being a fan of class B designs with their distortion, I prefer class A. Simplicity is a further attribute of the single ended class A design also. I also have a dislike of IC audio amplifiers, especially the LM386 with its noisy output.

This circuit uses yet another BC548 as the first amplifier and this is direct coupled to the AY8115 output transistor. The AY8115 is incidentally a Fairchild type unique to Australia and was made here.

A 600 ohm to 15 ohm transformer couples the AY8115 to the speaker or headphones. The external speaker and headphone sockets have not been shown on the circuit as their method of inclusion is obvious.

The collector load of the BC548 is the 4.7K resistor, which also supplies bias to the AY8115. There is a 56R emitter resistor for the AY8115 which operates in a bias stabilising circuit. The voltage drop across this biases the BC548 via the 15K. If the AY8115 current increases, the voltage across the 56R increases and the BC548 conducts more. This causes its collector voltage to fall which in turn reduces the bias on the AY8115. Across the 56R is a 1000uF capacitor to prevent reduction of gain. A sample of voice coil voltage is fed into the BC548 emitter out of phase, by means of the 3.3K and 100R resistors, so as to introduce negative feedback and a reduction in distortion. Output power is 77mW before clipping. If a transformer with an 8 ohm secondary is used instead of the 15 ohms specified, the 3.3K feedback resistor should be reduced to 1.5K.

The speaker transformer I used is a 600 ohm to 15 ohm line transformer. With a rating of about 3W, it is overkill for this circuit, but the large core gives a very nice bass response, especially evident when listening through decent headphones.



Inside view of receiver. The experimental origins are clear to see. At the back is the IF strip and detector. Left front sub chassis is the AF amplifier, and the tagboard at the right contains the VHF circuits.

Automatic Frequency Control.

Up to this point the circuit works fairly well. However, tuning was still fairly critical because the way the tuning capacitor had been earthed. Because it is a plastic type used in AM radios, the shaft is not directly earthed to the chassis, but rather through about 20mm of lead inductance. Although a plastic knob had been used, the shaft was still metal and some hand capacitance was evident. Ideally, the shaft should be directly earthed by means of a sliding brass contact, or better still with a panel mount variable capacitor where the moving plates are earthed to the mounting. This is another example of short leads having enough inductance to cause problems at VHF.

Despite the RF amplifier, there was still a slight amount of detuning when the aerial was touched.

Obviously, an AFC circuit would be desirable. Looking at the circuit, we need a point where the average voltage is proportional to the signal strength. The detector is no good because the signal has been clipped and will not vary in amplitude. The ideal point is the limiter collector. Here the average voltage rises with an increasing signal strength. A 10K resistor and 2.2uF capacitor filter out the pulse variation, providing steady DC.

As to how to control the frequency converter, it just so happens that the oscillation frequency does vary with the bias setting, and so this can be used to inject the AFC voltage. The voltage across the 2.2uF is introduced to the BF184 bias circuit via another 47K resistor.

In effect, the BF184 is stabilised three ways. Firstly by the collector feedback described previously. This sets the initial DC conditions. Secondly, this initial bias condition is optimised by the AFC voltage. The bias is automatically adjusted to the point where strongest signal is obtained. Thirdly, because the bias also controls the oscillation frequency, this too is optimised for maximum signal.

It is in fact quite practical to include a tuning / signal strength meter by monitoring the voltage across the 2.2uF. If a moving coil meter was to be used for this purpose, a suitable buffer with DC offset would be required.

The result of the AFC circuit is such that oscillation level control is no longer required on the front panel. It can be replaced by a trimpot.

Power Supply.

This is 12V DC at about 50mA. In practice, about 11 to 13V is suitable. A diode provides reverse polarity protection, and there are the usual electrolytics and decoupling circuits.

Performance.

Like all other single conversion pulse counting receivers, there are two tuning points; one each beside the carrier. This can be useful if there is interference because often better reception can be obtained by using the other tuning point. I strongly recommend a vernier drive for the variable capacitor. Direct knob tuning works, but with the low IF, tuning is very sharp. Sensitivity is about 30uV for the noise to start to drop off. In this regard, the circuit is comparable to the Fremodyne. At my location with just the chassis mounted telescopic aerial, all the main Sydney stations about 80km away can be received

clearly. However, it is not a DX set and the valve designs are still better for sensitivity.

The effects of having AFC is very noticeable with a much less critical tuning control, and touching or moving the aerial does not detune the receiver.

It was noticed that oscillator pulling was sometimes evident, before the AFC was added; this being because of the low IF. This does not seem to happen with the valve designs, possibly because the carrier voltage is considerably less than the voltage at which their frequency converters operate with.

The small 75mm speaker mounted in the cabinet lid does not do justice to the sound quality, and is provided merely for convenience. Much better results are obtained with a larger speaker.

Constructional Notes.

As with any other VHF circuit, layout and good earthing are important. It is amazing the amount of constructors who attempt to build VHF receivers on a solderless breadboard! These are the people that complain of unstable designs. Ideally, a metal chassis or box is the best kind of construction.

The oscillator coil is four turns of 18 gauge (or similar) tinned copper wire, self supporting air cored with a diameter of 10mm. The tap is at one turn. The particular tuning capacitor will determine the exact tuning range, but with the 60pF oscillator section of a plastic AM tuning gang, and the 33pF series capacitor shown, the range is 85 to 125MHz. There is of course further adjustment by means of the trimmer capacitor and by spreading or contracting the spacing of the coil turns.

A vernier dial will go a long way to make tuning easier.

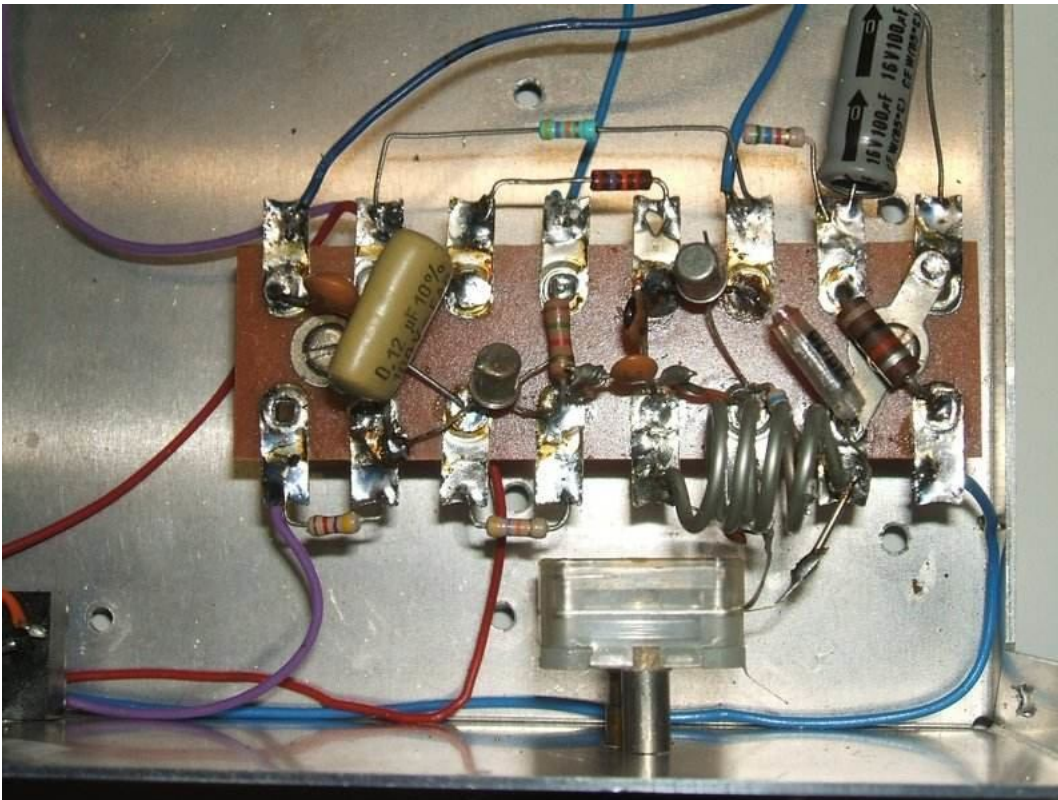
The front panel oscillation control shown on the prototype is a legacy of previous experiments and is no longer needed. A trimpot will suffice, and if results of the prototype are anything to go by, even that could possibly be dispensed with.

However, the transistors another constructor uses might operate better under different conditions, so do not be too hasty in omitting this control. In the prototype, mid setting of the control is satisfactory.

If for some reason, the AFC circuit is not required, omit the 10K, 2.2uF and 47K in that part of the circuit. The oscillation level control should be made available as a front panel control in this case.

The 680uF is an obscure value of capacitor, so use 470uF or 1000uF. Likewise, the .12uF associated with the oscillation level control can be replaced by .1uF.

For the AY8115 audio output transistor, any similar modern type can be substituted such as BD139.



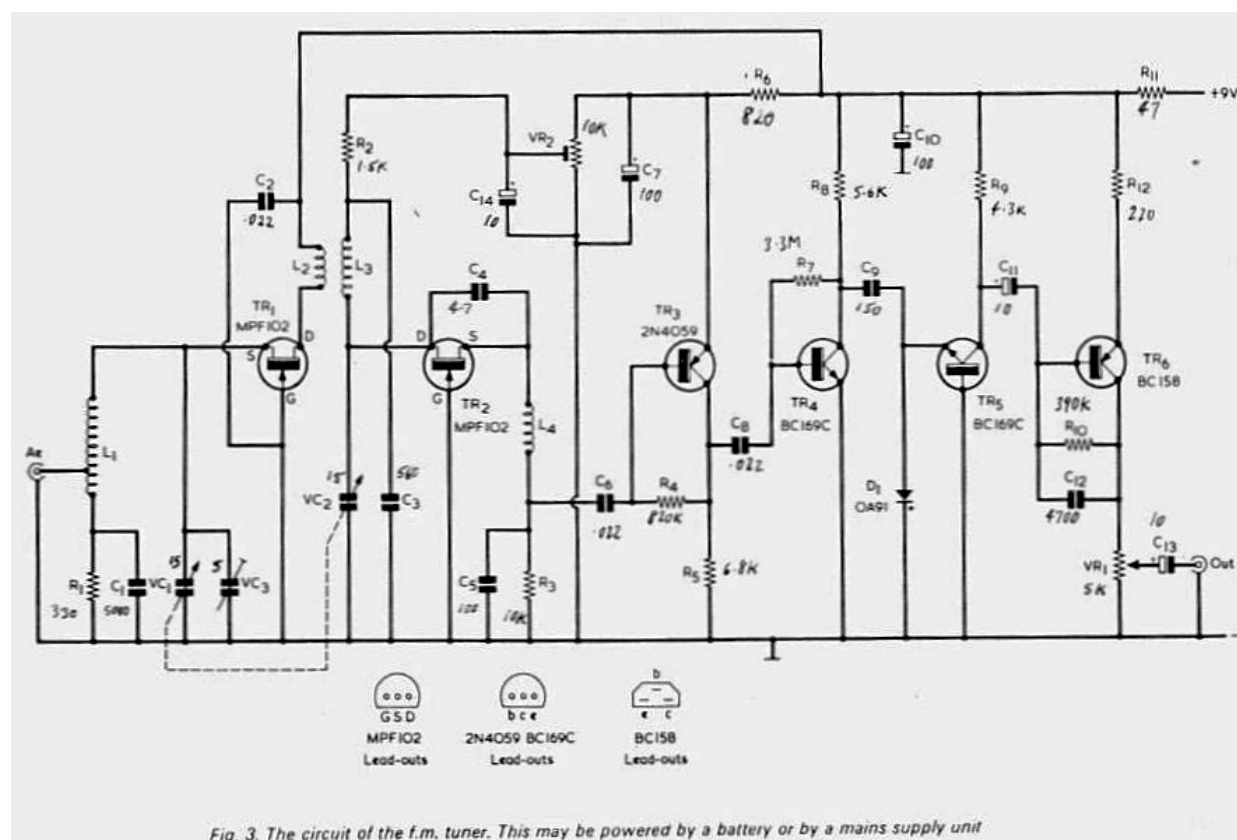
Close up of the RF amplifier and frequency converter.

As can be seen, I made up an aluminium box for the receiver, with a sub chassis for the audio amplifier and another for the IF amplifiers, limiter and detector. The RF amplifier and frequency converter are mounted on a tagboard right next to the tuning capacitor. The box is larger than required, but as this started out as an experimental receiver, I preferred a spread out layout so as to make any changes easy. Apart from the tagboard, all the transistors are mounted in sockets, and the construction resembles that used with valves. The receiver could be made much more compact using a PCB; something which is practical now that the design is finalised.

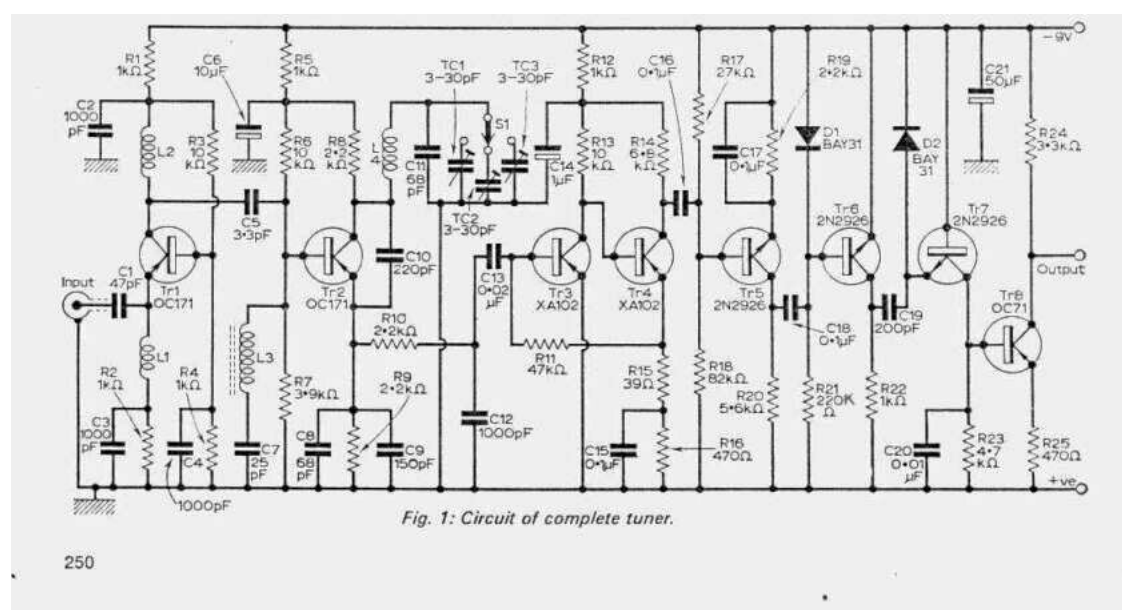
A 75cm telescopic aerial is mounted at the back corner of the chassis in an insulating block. This is more convenient for

portable use than having to use an external aerial, and gives more predictable results than a piece of wire. Note that 75cm is a quarter wavelength of the FM band.

Other Circuits.



From UK magazine "Radio & Electronics Constructor", December 1974 & January 1975. I found this to have the worst frequency conversion circuits of all I tried.



From "Practical Wireless" August 1967. The biasing of the IF transistors was unnecessarily complicated, and the operating conditions of the frequency converter critical. I was not impressed by the sensitivity either.

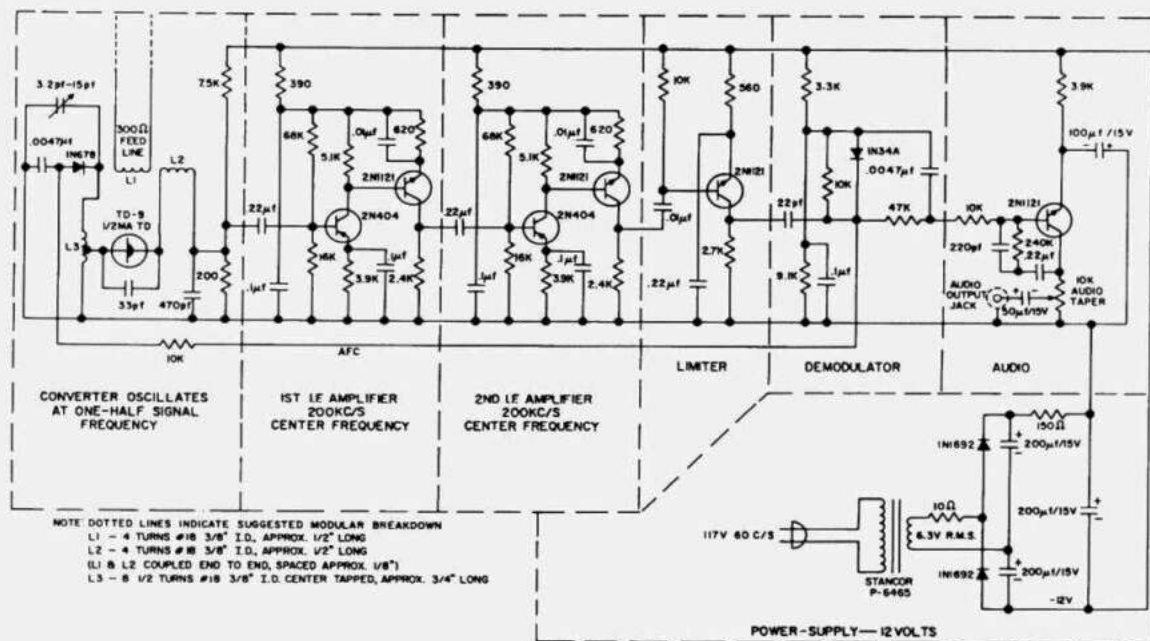


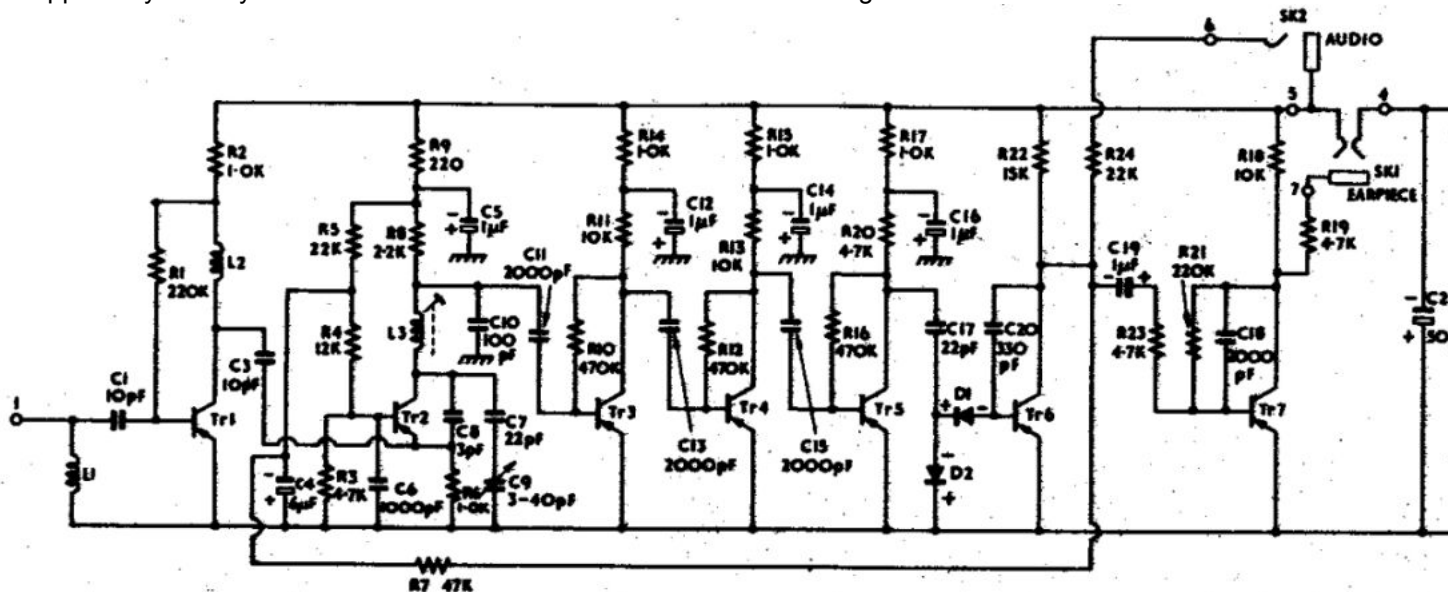
Figure 15.22

From the "General Electric Transistor Manual" 1964. It uses a tunnel diode for the converter. Again, the IF amplifiers seem unnecessarily complicated. I have not tried the circuit, although my previous experiments with tunnel diodes make me sceptical.

Sinclair Micro FM.

There was a commercially made kit, the Sinclair Micro FM, for sale in the UK during the late 1960's. It would be familiar to anyone reading 1960's English electronics magazines. It was a pulse counting circuit with untuned RF amp, autodyne converter, and used Micro Alloy Transistors. Claimed sensitivity was 3uV and the receiver could drive an earphone and had a line out socket for an external amplifier.

The few reports I've found on the internet suggest sensitivity was less than this. The PP5 battery required is obsolete, and was apparently already difficult to obtain at the time the Micro FM was being sold.



Circuit of the Sinclair Micro FM.

For those wishing to try building it, L1 and L2 are 14 turns around a 470K resistor. Wire gauge is not specified, but I'd guess about 25B&S. L3 is six turns around a plastic former with adjustable ferrite slug.

The former and slug would appear to be similar to the modern Neosid type of thing. Brief operation is as follows; Tr1 is an

untuned RF amplifier to prevent aerial loading, and to provide some gain (I'd guess about 10dB max). Tr2 is a self oscillating converter (i.e. autodyne). RF is filtered off by C10, leaving a 120 kHz IF. This is amplified by Tr3 and Tr4. Tr5 also provides amplification but is the limiting stage to provide a clipped waveform to the pulse counting detector. This consists of C17 as the differentiator, and D1 and D2 which are the diode pump. Tr6 provides audio amplification, with C20 integrating the detected pulses into a smooth audio waveform. Line level audio is available from this stage. Tr7 is merely an earphone driving stage. AFC is provided by using the DC at Tr6's collector to control Tr2's oscillation frequency. R7 and C4 are low pass filter to remove the audio component from the control voltage.



My Sinclair Micro FM receiver. This has yet to be restored.

From another Constructor:

Introduction

Hello all. My name is David Smith. I live in the UK near Manchester. I have written this because I have constructed John's transistor pulse counting FM receiver and been very pleased with the result. I have tried to set out the way I went about it and I hope that will encourage you to build it too.

I have had an interest in radio and electronics as a hobby since I was a boy. As a teenager I made a superhet FM tuner from a construction article in Practical Wireless (February and March 1969). That was a long time ago. I am retired now and am able to spend more time on my hobby. Since I retired, I have joined the British Vintage Wireless Society, restored several vintage valve radios, constructed a valve amplifier and made a number of other wireless related projects.

I was looking for something new to make when I came across John's website and read his articles on pulse counting receivers. These were not something I had heard of up until then. They seemed to have a lot of advantages and most importantly did not require complex equipment to accurately align tuned circuits. I thought the transistor pulse counting receiver was something I could tackle, particularly with the detailed article John had written about it.

Initial Assessment

Before starting any construction, I read and re-read John's article on the receiver until I was sure that I understood it. The design consists of three separate sections. First an RF section, then the IF section and last an AF amplifier that drives a small internal loudspeaker. I decided that I would omit the AF amplifier because I already had a suitable transistor amplifier with its own loudspeaker.

I wanted to understand in more detail how the limiter and discriminator sections worked and traced their origins back to an article in Wireless World magazine entitled "The Diode Transistor Pump" by D. E. O'N. Waddington, "Wireless World", July 1966. This and all the other magazines I refer to, can be found on the American Radio History website (www.americanradiohistory.com) which is well worth investigating.

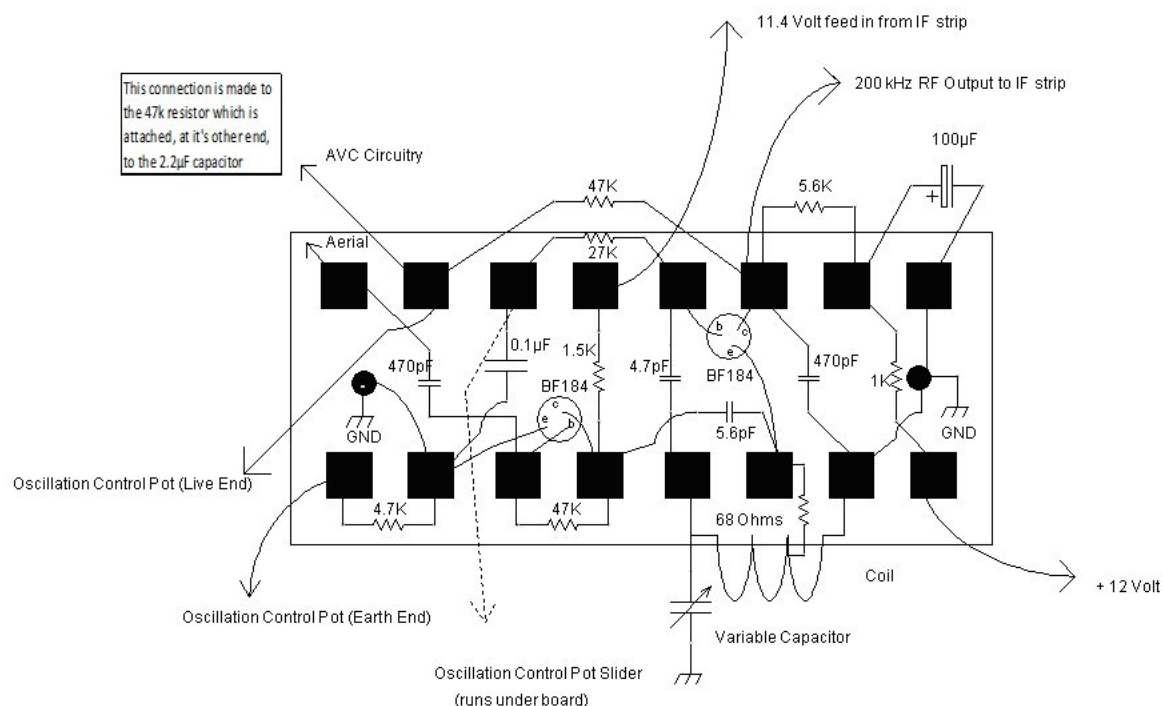
What I already knew about construction at VHF frequencies can be easily summarised; layout is critical, connections need to be short and a rigid metal chassis is necessary.

I knew this meant that construction of the RF circuit board and associated components would be the critical items. The IF stage operates at around 150 – 200 kHz and, as a result, construction would be much less critical.

RF Circuit Board

In order to stand the best chance of success I aimed to copy precisely the layout of the RF tag board that John built. I studied the circuit diagram and the photograph John had put in his article and very carefully sketched out the connections until I was sure I had them right. I did not find this easy and it took me quite a while to do. I persevered with this because I

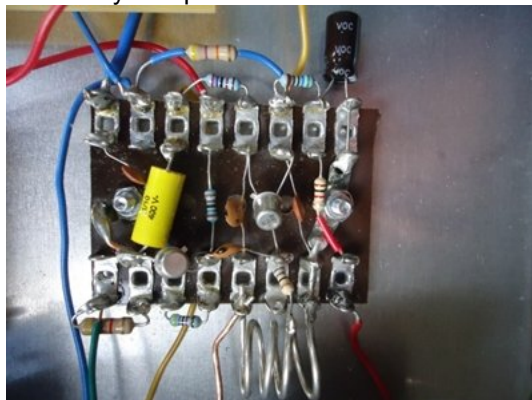
thought it was the key to success and I still do. I have redrawn this using a CAD program:



The drawing is actually full size and can be copied into a word processor and stretched out to fill a sheet of A4. If you decide to use this layout it is worth being sure you can tie up all the external connections with John's circuit diagram before starting construction.

I wanted to maximise my chance of success and so I used only the components specified by John. The coil is also exactly as specified by John: it is air cored and is four turns of 18 SWG tinned copper wire wound on a 10mm diameter former. It is clearly visible in the photograph below. The tuning capacitor is a 15pF air spaced variable fitted with a slow motion drive; I got this from a scrap VHF valve radio given to me by my brother.

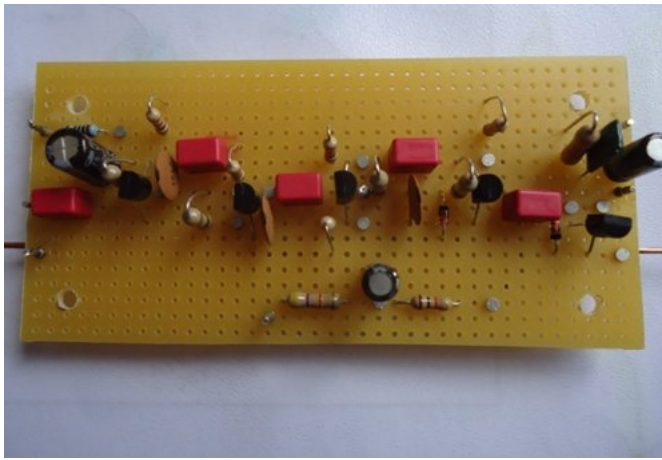
This is my completed circuit board – I have orientated it to match the drawing above.



IF, Limiter and Discriminator Circuit Board

In comparison to building the RF section, construction of the IF amplifier and discriminator was straightforward. I simply followed the circuit diagram when building the board. I wanted to make the board reasonably small without trying to overcrowd it and, having assessed the physical size of the components, I concluded that a piece of plain 0.1 inch strip board of about 4 inches by 2 inches would be satisfactory. I used the components specified by John and hard wired them together.

This is my completed circuit board:

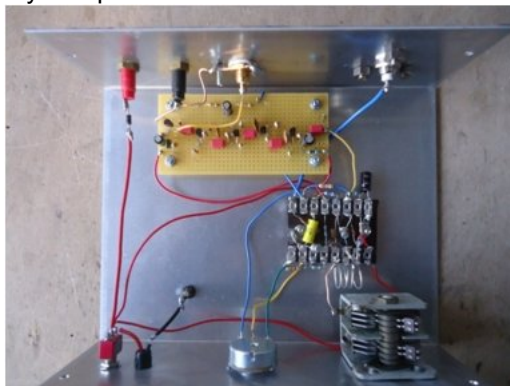


Assembly of the Receiver

For a chassis, I used a two part aluminium box of 8" x 6" x 3" (WxDxH) that would provide a rigid mounting and a good earth plane. A die-cast box would also be suitable and easier to find too.

I prepared a layout diagram for the chassis and ensured it matched the arrangement shown in John's photographs as closely as possible. I drilled the chassis to accommodate the various controls, circuit boards and sockets in accordance with the layout drawing. I loosely fitted the various controls, circuit boards and sockets on to the chassis to ensure there would be no nasty surprises later on. After that, I wired up the tuner. I added an LED On/Off indicator which was my only deviation from John's design.

My completed tuner is shown below:



Testing the Pulse Counting Receiver

I connected an indoor dipole aerial to the receiver and an external audio amplifier. The radio immediately worked properly with all the local FM stations coming in clearly. I did not need to make any alterations to the tuning coil or anything else for that matter. The slow motion drive made tuning easy and I quickly found that the set was very stable, quiet in operation and provided excellent sound quality with no noticeable sibilance. There were no hand capacitance effects and no hiss when tuned in. The oscillation level control needs little adjustment in use and is not particularly sensitive; the mid-point of its travel is about the right setting. Only about a quarter of the FM tuning capacitors range is used in covering 88 – 108 MHz but with the slow motion drive it isn't really a problem and I did not attempt to alter it.

With a 12 volt supply the current drawn is 24mA. I did try running the receiver from a 12 volt switched mode power supply; this was a bad idea – the noise introduced was intolerable. I eventually bought a 12 volt DC supply using a traditional mains transformer and this was entirely satisfactory with no additional hum or noise whatsoever.

Conclusion

I am very pleased indeed with this receiver. I planned the construction carefully, used exactly the components specified by John, and tried to follow all his advice on construction. I now have an FM tuner that receives all the stations I am likely to want to listen to, sounds excellent, does not drift in frequency, needed no alignment and has nothing to go out of adjustment. Like all simple pulse counting receiver designs there are twin peaks for tuning each station but you soon get used to that.

With the exception of the tuning capacitor all of the components are readily available. Suitable air spaced tuning capacitors do come up on eBay, and elsewhere, from time to time and are worth keeping a lookout for; otherwise you could use a polyvaricon as John did.

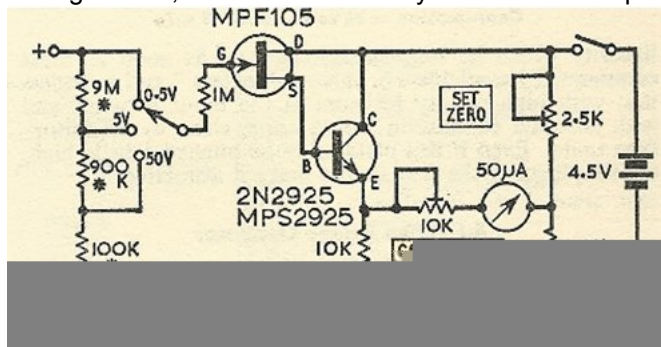
Addition of a Tuning Indicator

After building this receiver I could not resist trying John's [valve based pulse counting receiver designs](http://members.iinet.net.au/~cool386/sspcrx/sspcrx.html). These too were

excellent. I built design No.5 which has the magic eye tuning indicator. This showed me the value of such a device for accurate tuning. I kept thinking about the comment John had made in his article that a tuning indicator could be added to the transistor version by measuring the voltage across the 2.2 μ F capacitor in the AFC line.

The first thing was to get some idea of the AFC voltage. I have a digital voltmeter and trying to get an accurate measurement with this was difficult; eventually I found that 4.6 volts was the maximum I measured with the receiver tuned in to a strong local station. At least this gave me something to start with.

I looked for a suitable analogue voltmeter circuit and after some time I came across the circuit below. It looked ideal. It is reasonably simple, has a high input impedance, runs from a single positive rail supply and, with suitable voltage dropper arrangements, I saw no reason why it should not be powered from the tuner's 12 volt supply.



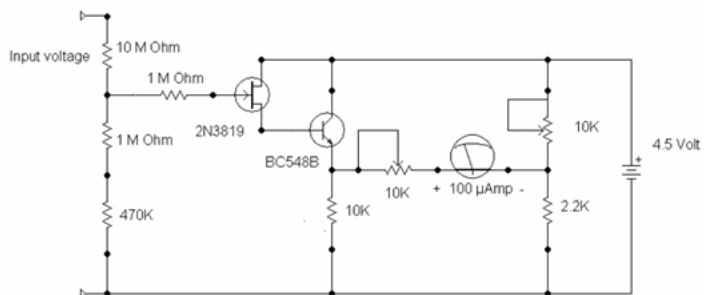
This circuit is from a design first published in Electronics World in February 1967, but with some modifications suggested by another correspondent to that journal in the November 1967 issue. Initial reports on the circuit as a voltmeter were enthusiastic. These two articles are worth reading if you are interested in adding the tuning indicator to the receiver.

Preliminary Tests

I built a test circuit using a 2N3819 (Fairchild) FET and a BC549C NPN transistor. I used these transistors because I had them to hand; I don't think they are at all critical and anything roughly equivalent is worth trying. I used 10k linear potentiometers for both the set zero and calibration controls. I used a 100μA meter and built the voltage divider exactly as shown above. I powered it from a 4.5 volt battery. The set zero control was adjusted so that the meter read zero when there was no input voltage applied and the calibration control was adjusted so that a 3 volt test voltage read correctly. I was impressed with the circuit. It worked well and made a good analogue voltmeter. There were no problems with it and I found that it could quite happily measure its own supply voltage, meaning that with suitable switching you could perhaps use it as a "battery condition" indicator as well as a tuning indicator. I used this test circuit to measure the receiver's maximum AFC voltage, which was easy to do as the analogue meter clearly showed the peak. I was pleased to find that 4.8 volts was the maximum I measured; not so very different from that which I had measured with such difficulty using a digital meter.

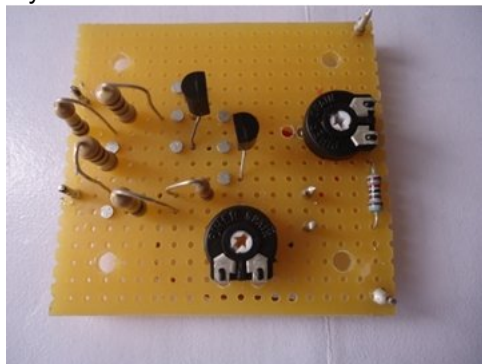
Building the Circuit

Satisfied that the design would be suitable I now made up the circuit on a small piece of plain strip board using two 5k trimmer potentiometers for the set zero and calibration controls. I used the same two transistors that I had used in my trial construction. I devised a simple voltage divider for the input and switched on. When I tested it, I found to my annoyance that the two 5k trimmer potentiometers did not give enough range to adjust the set zero and calibration controls properly. I should have used 4.7k potentiometers in my test circuit instead of 10k ones – it would have saved me quite a lot of trouble. There followed a degree of experimentation. The underlying cause quickly became plain. The variation in FET parameters is so great that a circuit must have sufficiently wide-ranging adjustment to deal with this. This is hardly a new observation. I made a new version of my test circuit. This time I used a new 2N3819 FET (Motorola) and a new BC548B silicon transistor. The voltage divider I used at the circuit input had a 10M resistor in series with a 1M and 470k resistor. As before, I used 10k linear potentiometers for the set zero and calibration controls. This is the circuit diagram:



Only when I was satisfied that this version worked perfectly did I re-build the circuit on a small piece of strip board for inclusion in the receiver. This time I used two new 10k trimmers for the set zero and calibration controls. The circuit was powered from a 4.5 volt battery. The set zero control was adjusted so that the meter read zero when there was no test voltage applied and the calibration control was used to give Full Scale Deflection with a 6 volt input voltage. This time everything worked perfectly.

My final version:



I measured some voltages and currents; the emitter voltage of the BC548B with the 100 μ A meter disconnected was 1.08 volts (for comparison the earlier version with the Fairchild FET had been 1.8 volts). The total current drawn was 0.6mA with no input voltage rising to 0.7mA when measuring 4.5 volts; the earlier version had drawn 1.1mA. These variations in voltages and currents reflect the variability of FETs.

Installation of the Tuning Indicator

First, I needed to ensure the tuning indicator would operate through a suitable voltage dropper from the tuners 12 volt supply. The simplest way of doing this was to use a voltage dropper resistor in series with the positive supply lead. I was aware there might be problems with doing this but a 12k resistor in series with the positive supply line turned out to be entirely satisfactory giving me 4.6 volts as the tuning indicator supply voltage. Some minor adjustment of the set zero and calibration trim pots was needed but that was all. Other FETs might require a different voltage dropper from the 12k I used. The easiest thing to do is to measure the current drawn using a 4.5 volt supply and calculate the dropper resistor you will need to bring your supply line voltage down to 4.5 volts; something in the range 10k to 12k should do it.

In order to make room for the panel meter the oscillation control potentiometer needed to be moved closer to the tuning capacitor. I used a new miniature 4.7k linear pot to replace the original standard size item.

A 50mm hole was now required for the meter; a tedious job with much drilling and filing of metal required. The final stage was to mount the tuning indicator circuit board. I took the input to the tuning indicator from the positive terminal of the 2.2 μ F electrolytic capacitor in the AFC line. This is the point recommended by John and it is from the final IF amplifier transistor before the limiting stage.

For clarity I have included the final circuit diagram of the tuning meter:

All the components were connected up; and the tuner tested. All was well. The tuner worked just as before and the tuning indicator gave a very clear indication of when a station was correctly tuned. It does also give some idea of relative signal strength.

I re-adjusted the set zero trimmer so that there was only minimal meter reading when tuning between the main BBC stations around 91 MHz and then re-adjusted the calibration trimmer so that my strongest station (BBC Radio 4 on 93.7MHz) gave me a reading of 80% FSD. Because there is no inter-station muting the meter does respond to the background noise between stations but tuning stations in correctly is very easy to do.

This is the final version with the meter and circuit board installed:

Conclusion

The tuning indicator is a nice addition to the tuner. The circuit is entirely suitable for the task. It gives a clear indication of when stations are correctly tuned. The tuning indicator confirms that the receiver is very stable in use. I have left it switched on for hours with no discernible drift – a testament to the very effective AFC circuitry John has designed for this receiver. Because some minor adjustment of the set zero and calibration trim pots was needed after installation I no longer think the circuit can easily be used to check the tuners supply voltage.

Other than the problem with the FET variability there were no other complications and I am pleased that I made the effort to add the tuning indicator to this excellent receiver design.

I let John know by email what I was doing and he has given me every encouragement throughout for which I am very grateful.

D J Smith
14 July 2017

Transistor Pulse Counting FM Tuner – August 2017 Update

After I had completed the work on the tuning indicator, I discussed the matter by email with John. He suggested that a couple of alterations to the design might be worth considering.

First, that it might be better to use a Zener diode to generate the 4.5 volt supply the tuning unit requires rather than just use a simple dropper resistor in the 12 volt supply line. Second, that it would be nice if the unit could also be used as a “battery condition” indicator so that a user could easily check the battery voltage. I said I would investigate these two suggestions and let John know what I found.

First, I investigated John’s suggestion about the Zener diode. I compared my simple dropper resistor arrangement with a 4.7 volt Zener diode fed by a 1k Ω resistor.

Of course, I found that the Zener diode arrangement maintained the 4.5 volts required by the tuning unit far better than the dropper resistor alone. The receiver requires 11 to 13 volts for normal operation and the Zener diode regulation over this input voltage range is quite adequate. With the Zener diode in place, the tuning unit draws 7ma compared with 1mA with a voltage dropper resistor. However, I think the improved voltage stability is well worth the small extra current drawn and I have added this to my receiver.

Next, I investigated John’s second suggestion that the tuning unit could, by means of a voltage divider and a suitable switching arrangement, be used to monitor the battery supply voltage. However, I found that when the supply voltage dropped below eleven volts the “set zero” function of the tuning unit went out of adjustment; the 100 μ A meter showed an increase in current flowing through it and thus an incorrectly high battery voltage reading. The Zener diode regulation was not good enough for this purpose and I did not want to increase the Zener diode current because of the adverse effects on battery life. This was not the right solution and I considered how else I might approach it.

I thought it might be worth considering an arrangement using just the 100 μ A meter movement with a 200k Ω series resistor. This would give a voltmeter scale reading 0 – 20 volts; it would not have a very high input impedance but this would not matter when reading the supply voltage. A two-pole change over switch and a single resistor would be all that was required

as shown here:

This arrangement is not dependant on the functioning of the tuning unit electronic voltmeter and always gives a correct indication of the battery voltage. A test showed the meter and a 200k Ω resistor worked well as a voltmeter. With 12 volts applied the meter read 60 μ A; the user simply doubles the meter reading (or divides by five) and interprets the result to get 12 volts. With a 0 – 100 meter scale some sort of mental arithmetic is going to be necessary whatever arrangement is adopted.

This arrangement was so simple and so satisfactory that I incorporated it into my revised design. The final design is shown here:

This is the circuit board I built:

To setup the unit connect a 12 volt power supply to the circuit and adjust the “set zero” trimmer so that the 100 μ A meter reads zero. With the input voltage divider values shown in the circuit diagram above (10M Ω + 820k Ω) the meter has a Full Scale Deflection of 6.6 volts. Knowing that, you can then apply any convenient known input voltage (say 4.5 volts or 6 volts) to adjust the “calibration” trimmer so that the meter reads correctly.

This is the receiver with the board installed:

The small red toggle switch to change between the “battery condition” indicator and tuning indicator is visible between the meter and the tuning capacitor.

A front view of the revised receiver, tuned to a strong local station:

Conclusion

The suggestion that John made about using a Zener diode for regulating the supply voltage to the tuning indicator was very worthwhile and I adopted it. The only drawback is the small additional current drawn due to the action of the Zener diode. I have also been able to add the “battery condition” function although not in quite the way we originally discussed. The simple arrangement I have installed in my version of this receiver works whatever the state of the battery.

If you decide to construct the tuning unit you will find the circuit is trouble free. The only recommendation I would make is to ensure that you do use 10k Ω trimmer potentiometers for the “set zero” and “calibration” controls. If you use lower values you may be lucky and find they work satisfactorily but it depends on the characteristics of the FET you are using. I have not found any FETs where even 10k Ω trimmers have not given enough adjustment range. If you happen to have just one 10k Ω trimmer, and are tempted to try your luck, then use it for the “set zero” function.

Finally, I am grateful to John for his helpful suggestions that have resulted in alterations to the tuning unit which costs little to implement and add worthwhile improvements to the design.

David Smith
03 August 2017

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