A Non-Invasive FM Converter for AM Radios

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Introduction

In my opinion, there is nothing finer than an authentic vintage radio from the '30s or '40s. A properly restored radio from this period can be reliable and safely used daily. However much I love them, I do not actually use them very often because there is very little appealing programming on the AM band. I firmly believe that permanently altering an antique radio in any way is desecration, so until now, I have contented myself with fixing them up and shelving them.

It does not have to be this way, however. I have devised a module that plugs into the converter (otherwise known as first detector or mixer) tube socket and turns the formerly AM radio into an FM radio. No alterations to the radio itself are necessary, except for replacing the tube with this module. Even the tuning mechanism of the radio works as before, except that it now tunes the FM band. It is small enough to fit into most radios of this vintage.

Theory of Operation

The circuit consists of 4 sections. Central to the device is a single chip FM receiver. This receiver uses a varactor diode to allow voltage controlled tuning. The second section is a frequency to voltage converter (actually a phase locked loop) that taps a signal from the host receiver's local oscillator. As the receiver is tuned, the LO frequency changes, and a voltage appropriate to tune the FM receiver is generated. The third section is a modulator that modulates an IF oscillator with the audio output from the FM receiver. This signal is injected into the IF of the host radio. The final section is a power supply that generates DC for the other parts from the filament voltage of the host receiver.

Although this may sound somewhat complex, integrated circuits make this fairly straight-forward to reproduce.

The FM receiver is based on the Philips TDA7088 single chip FM receiver. This chip is used in many portable FM radios. In fact, the only sensible way to proceed is to purchase one of these radios rather than trying to purchase the chip and surrounding parts. These radios are very common, and are usually available for under $10. They can be distinguished by their tuning buttons: they do not use "knob" or slide-rule tuning, instead they have a "seek" and "reset" button. Part of the IC function (that is not used in in this converter) is an automatic search push-button tuning system: reset tunes the radio to the bottom of the band, and seek tunes up to the next higher station. Every FM radio that I have seen that has these two buttons is based on the Phillips TDA7088 IC (whether or not the IC is labeled as such). I have seen this radio built into a pen ($9), into a plush soccer ball ($15), blow-up pillow, and stand alone. Wall-Mart has one (up next to the cash registers) for $10, Pharma Plus has them for $10, Wallgreen Drugs is selling them in the US for $2.50 US, you can get them at the Stittsville Flea Market for $5 and some haggling, but Paul Guibord pointed out that the best bargain can be found at Giant Tiger, where they are $1.97! The one that I am referencing for this design is from Wall-Mart, but the modifications required to the receiver are so minor that any of these receivers will do.

Although the TDA7088 is intended for low cost, portable applications, its performance is actually pretty good, and much better than the host AM receiver. It boasts <2% distortion, and 3uv sensitivity. The operation of this chip is quite clever. To simplify the IF filtering to the point that standard R-C active filters can be used (instead of the carefully tuned 10.7MHz transformers in a normal radio), a 70kHz IF is used. In order to squeeze the wide FM signal into this narrow band, the FM local oscillator is tuned to follow the audio frequency modulation on the incoming FM signal, thereby reducing its effective bandwidth. This has an added bonus of free AFC, and a form of image rejection.

To implement the frequency to voltage converter, I used a single chip phase locked loop (PLL) device, because it is completely insensitive to amplitude changes, and results in a very linear transfer characteristic. The PLL generates a voltage that increases with frequency, but the FM receiver requires a voltage that decreases with frequency, so a low voltage op-amp, the LM358, performs a translation. I used the ubiquitous NE602/NE612 oscillator/mixer chip, which will be familiar to hams, for the IF oscillator and modulator. This chip needs a bare minimum of external components, is easily available, small, low power, and pretty fool-proof.

Construction

I have assembled this circuit in two pieces: a tube adaptor that plugs into the host radio and accepts the converter tube, and the main module that contains the rest. These are shown in Figure 1. Someday, I will assemble one in an octal relay enclosure.

The schematic is shown in Figure 2. In this schematic, I assume that you have acquired a fully assembled portable radio with electronic tuning, such as the Wall-Mart "Ice Radio" (shown in Figure 3). Note that the chip may or may not be marked with the 7088 number or the Philips logo. Five connections need to be made to this radio:

A: Audio output: This will be from a 0.1uF (typical) capacitor connected to pin 2 of the TDA7088. There will be a 22K resistor in parallel with a 0.0018uF capacitor from this pin to ground which should be left in. Disconnect the 0.1 uf capacitor from the audio amplifier, and take point "A" from the end of the capacitor.

B: Tuning input: This is the “Reset” button. One side of this switch will be connected to the positive supply, the other can be used to voltage-tune the receiver. There is no need to remove the switch.

C: Positive supply; the red lead to the battery compartment or pin 4. Note that either the black lead or red lead will be interrupted with the on/off switch. This switch must be disabled (shorted).

D: Antenna: In every radio I’ve taken apart, the earphone wire acts as an antenna. There will be a connection from capacitors connected to pins 11 or 12 of the TDA7088 to the earphones. There may be an inductor or transformer providing RF isolation for the earphone wire so that it can be used as an antenna. You can tap an antenna wire anywhere along this circuit.

E: Ground: the black lead to the battery compartment, also pin 14 of the TDA7088.

A few things to note during construction: C3 and C4 should be close to U1; C7, C8, C9 and T1 should be close to U4; and C12 should be close to U5. U1 is a 74HC4046; the more common 4046 or 74C4046 will not operate at a high enough frequency at 5 volts. If you use a *Philips* 74HC4046, you will need to adjust R13 or R14. The NE602/NE612 is commonly used by hams and should be available at their flea markets. All ICs are available from Sayal Electronics. T1 is an IF transformer (not the oscillator coil which has a red core) from any transistor radio. The two terminal secondary is not used. The coaxial cables from the “Tube Adaptor” to the main unit should be less than one foot long. D3 is simply a convenient way to drop the 5 volt supply down to the 3 volts used in the FM radio section. It need not be visible.

I constructed the main unit on a bare copper clad board, mounted in a box for protection. Figure 4 shows the resulting rats-nest. Note that the ground in the converter circuit is not necessarily the same as the ground on the host receiver; they should not be connected. This implies that the coaxial cables from the tube adaptor must be insulated, and the unit should be mounted in a plastic box. Note also that if this is used in an AC/DC set, the unit could be “hot” all over, so make sure it is properly insulated, and use appropriate precautions when installing.

The tube adaptor is an octal base from an old tube, with an octal socket for the converter tube, which is still used. The schematic shows connections for a 6SA7 converter tube, but with the appropriate changes to hardware and pin connections, it should be possible to use this with almost any converter tube, such as 6A8, 6A7, 6BE6, 7A8, 6L7 (which is really just a mixer). Tubes with 12 volt filaments can also be used, but add the 22 volt zener diode D7 as series strings can have nasty turn-on voltage transients. It may also be possible to use this with 12-volt plate car radio tubes, but I have not tried.

Alignment

Make sure the host AM radio is in good working order. Remove the converter tube, plug it into the adaptor, and plug the adaptor into the radio. The adaptor requires only a short antenna of 6 inches or so.

T1 must be adjusted so that the oscillator is operating in the middle of the IF of the host receiver. The screw in T1 should be adjusted for maximum volume in the host receiver.

R15 sets the carrier level in the modulated IF signal and should be adjusted to provide distortion-free audio.
The FM receiver will be set up so that the low end of the FM band is received when the tuning voltage at “B” is at about 3.3 volts (the receiver’s positive supply). If the full band is not received as the host receiver is tuned, then perform the following adjustment: First, verify that the voltage at F varies smoothly from about 0.7 to about 3 volts as the host receiver is tuned across the band. If this is not the case, R6 and R7 might need adjusting. Once the voltage at F is varying appropriately, R13 determines the location of the center of the band, and R11 determines the tuning width. These can be experimentally modified until the radio tunes appropriately. Audio should be present at point A as the radio is tuned across the band by adjusting the voltage at point B from about 1 to 3.3 volts.

Modifications

It should be possible to use this circuit with any superheterodyne. For example, a ‘35 or ‘24 tube is sometimes used as a mixer, but the way the LO is injected varies, so application will depend on the individual receiver. Also, these receivers often have a lower IF of 262kHz or 175kHz, so the value of the IF oscillator inductor will need to be adjusted. (Or add parallel capacitance). It could be used with a TRF receiver if one of the tuned RF stages can be made to oscillate. The output signal would be fed into the detector stage. The lack of AVC in these receivers will make setting the audio levels more critical. Another option could be to eliminate the IF oscillator and modulator, and feed the audio directly into the phono input of the host receiver. A problem with this scheme is that the converter and IF stage of most receivers is turned off when the receiver is set to phono operation.

There are obvious simplifications that can be made. The unit can be tuned with a potentiometer (a 50K potentiometer from ground to point C with the slider connected to point B) and all the circuitry around U1 and U2 eliminated. The modulator, U4, can be eliminated and the audio from A can be fed directly into an audio amplifier.

Performance

How well does it work? This unit picks up all the local FM stations well with a 6" antenna, however, they all “sound like” AM stations; that is the high frequency response of AM receivers is typically not more than 3-5kHz, and this limitation becomes quite apparent. (You could try to stagger tune the host receiver IF transformers to improve high frequency response) And, the envelope detector used in most AM receivers introduces distortion. So, you’ll find the receiver works much like it did before, but with much improved programming.

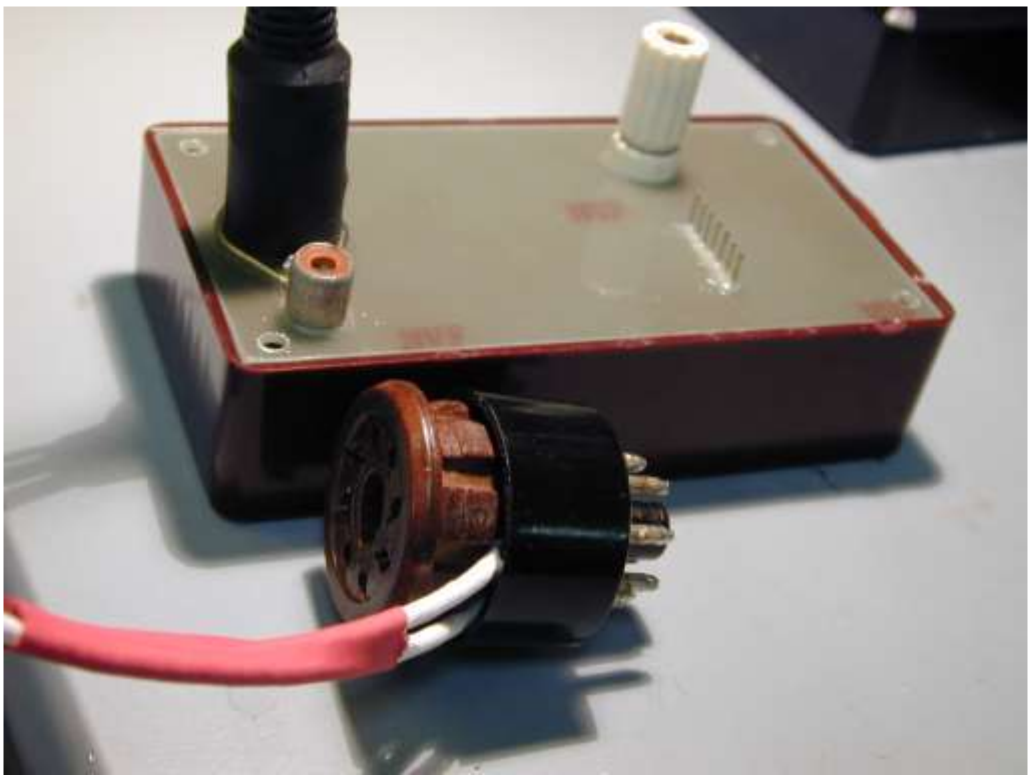

Figure 1: Photograph of the converter in its 1" X 2" X 4" box, and the tube adaptor.

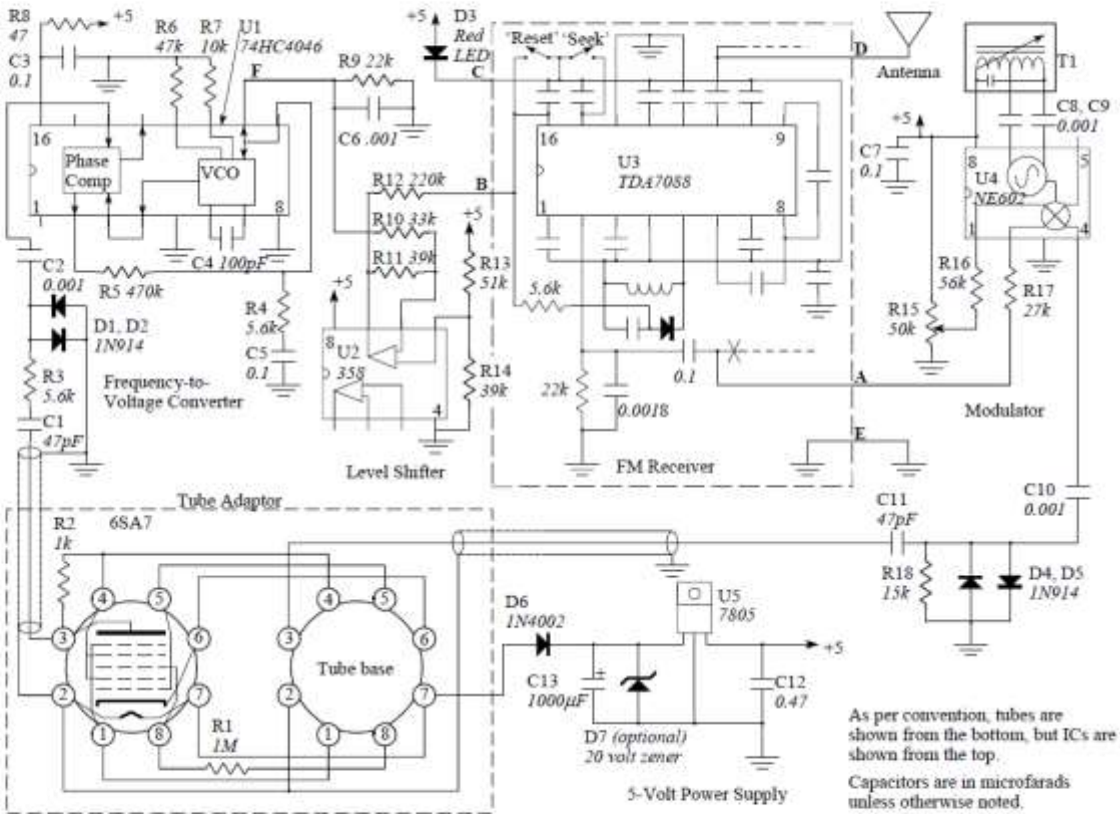

Figure 2: Schematic diagram of the converter.

Figure 3: A radio "before"

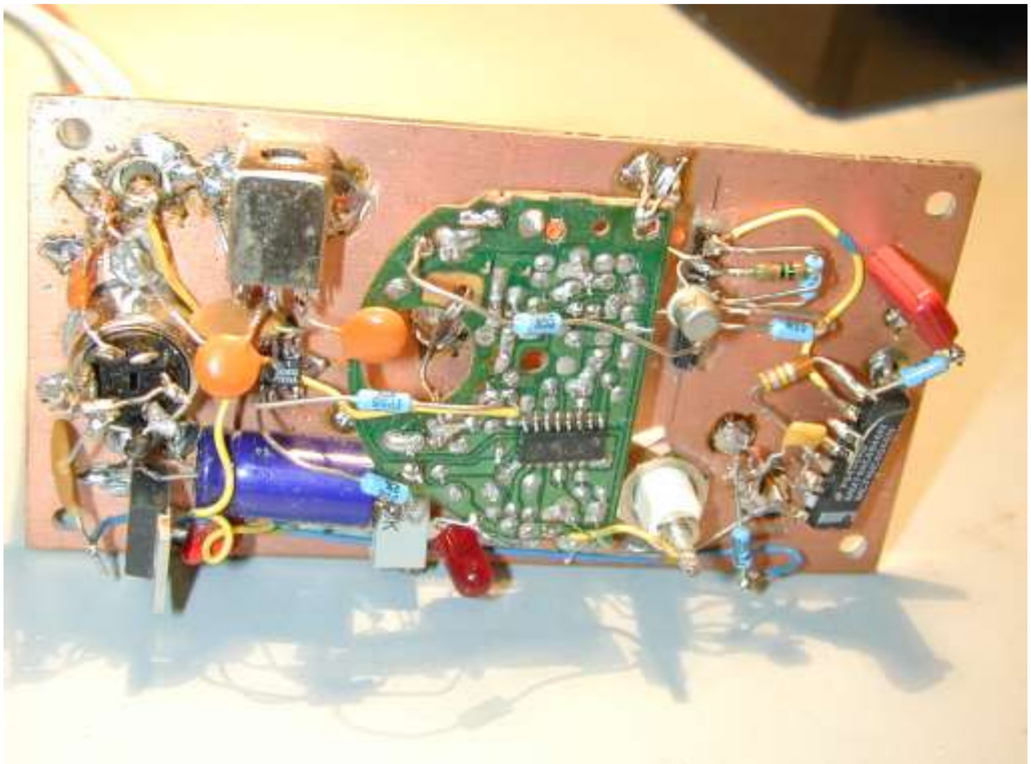

Figure 4: Photograph of the inside of the adaptor. Note that the circuitry surrounding U2 is different than in the schematic.