The MiniMod by Ian Liston-Smith

The battery-operated MiniMod uses the headphone output of any portable audio player to generate an amplitude-modulated signal for reception on a nearby medium-wave radio.

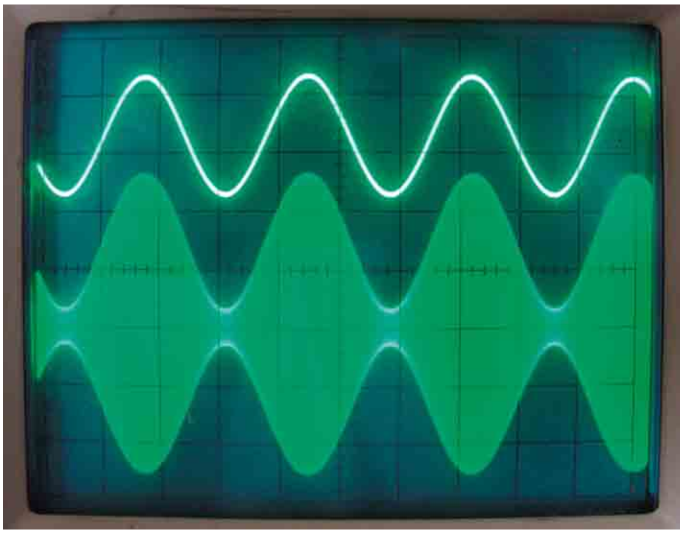


Photo 1: Upper trace shows 1 kHz audio input. Lower trace shows undistorted modulation envelope

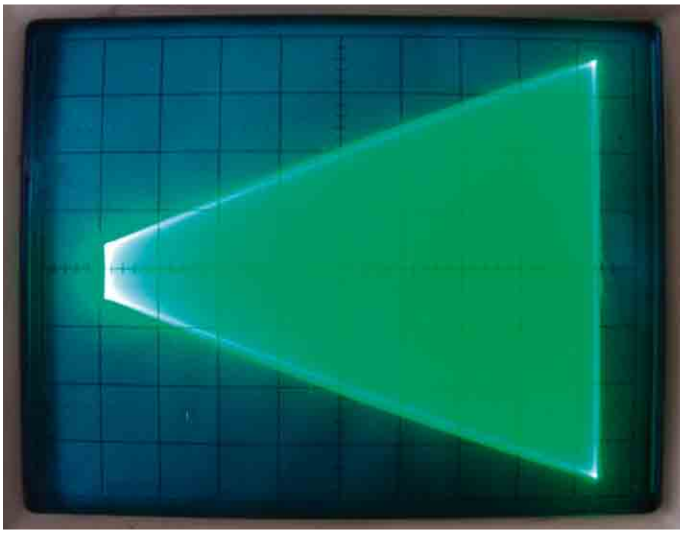


Photo 2: Trapezoidal trace shows straight edges and no distortion

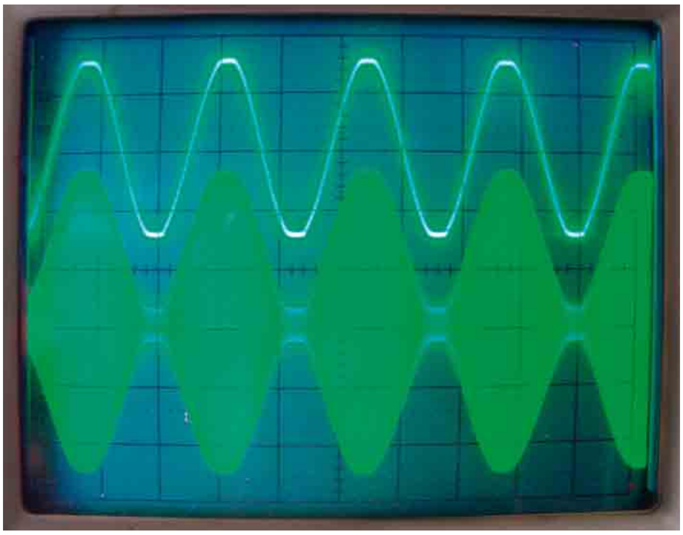


Photo 3: Symmetrical clipping starting beyond about 80% modulation depth

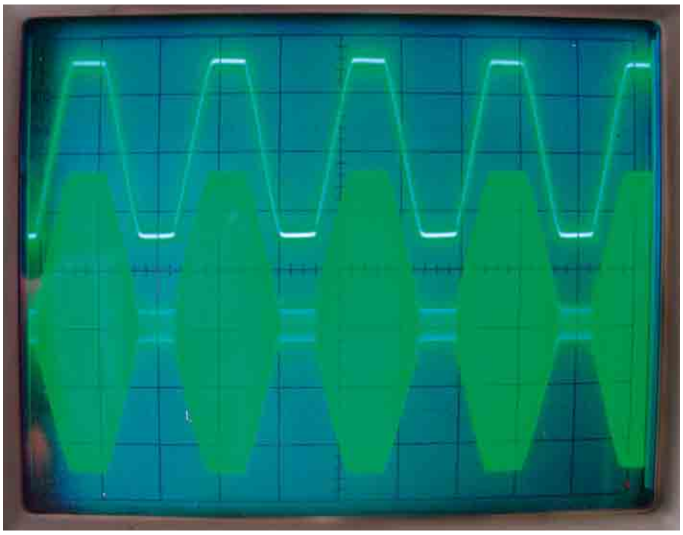


Photo 4: Severe over modulation!

With the declining number of medium-wave stations on an increasingly noisy band, it is getting harder to enjoy our vintage sets. For these reasons, various mini medium-wave transmitters have become available so we can tune into our own "stations". These devices vary in complexity, sound quality and price, but if you can restore a vintage radio then you can build the circuit described here. Small modulators need not be complicated to work really well.

I have designed AM transmitters for Ofcom-licensed medium-wave stations so it was a challenge to see what I could do with a few components to produce a nicely modulated signal from a simple solid-state device with a range of only a few feet.

The huge variety of free internet podcasts on any subject under the sun, together with plays, audio books and of course music, makes such a gadget very useful when it is inconvenient to listen via the computer or to wear headphones, whether listening on a vintage radio or not.

If you are not squeamish about covering your home and garden with a stronger signal, then see the simple three-transistor, crystal-controlled design "Generating an alternative MW programme source" in BVWS Bulletin volume 25 number 3 - Autumn 2000. If you prefer something with a limited rage, then this no-frills design is for you…

Design requirements

High quality sound: There is no point restoring a radio to work as it did when it left the factory if it ends up faithfully reproducing a poorly modulated signal. As can be seen from photos 1 and 2 there is no significant distortion on the modulated carrier when properly adjusted.

Simplicity: I have seen some designs using dozens of components to include audio processing, frequency synthesis and modulation depth indicators - all essential features for a "real" transmitter. And to do these things well, complexity is inevitable. However, for a simple device radiating little more than the local oscillator of the radio receiving it, I don't think they're necessary.

Headphone audio feed: MP3 players are widely available and cheap – less than £10 in some cases. If you own a CD- or Walkman-type player, the headphone output from these is equally suitable.

Battery operation: The total current consumption of this device is only about 8 mA so will run for many hours from a 9-volt PP3-type battery. Battery operation also reduces the risk of modulation hum in mains-powered radios when the signal source is very close. The MiniMod will continue to work well until the battery falls to about 5 volts.

Reproducibility: In order to appeal to home constructors, a design must not contain obscure junk-box parts. All the components used here are freely available. Inductors L1 and L2 are available from one main UK

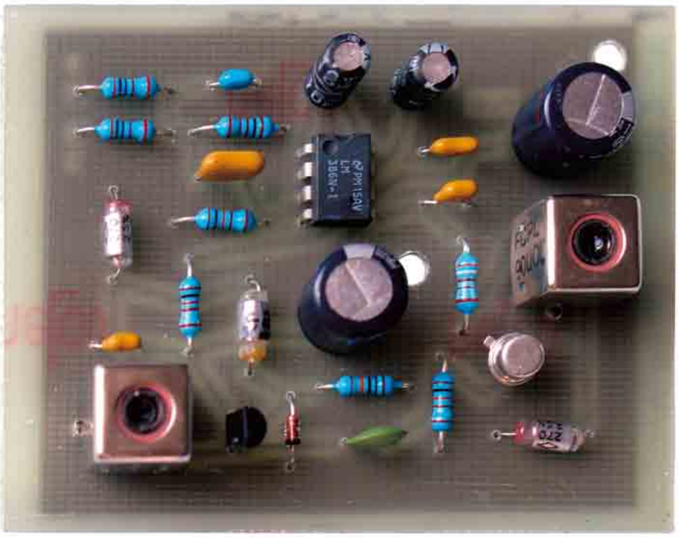
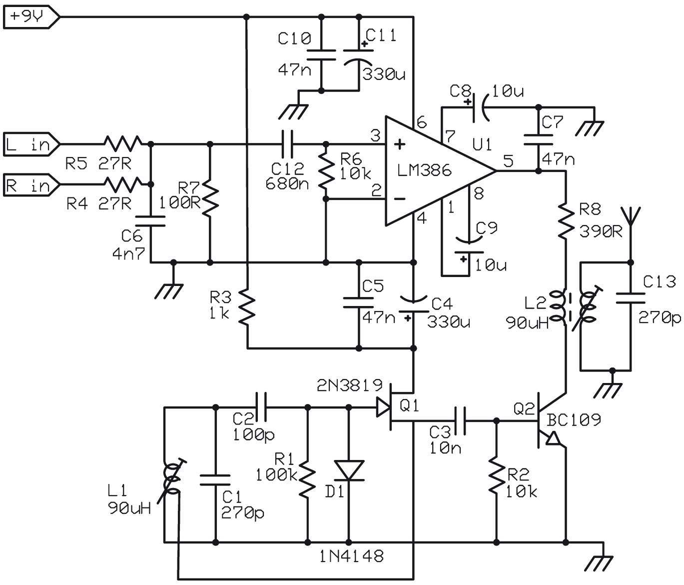


Photo 5: The circuit board



Components list

C1	270pF	R1	100k
C2	100pF	R2	10k
C3	10nF	R3	1k
C4	330µF	R4	27R
C5	47nF	R5	27R
C6	4.7nF	R6	10k
C7	47nF	R7	100R
C8	10µF	R8	390R
C9	10µF		
C10	47nF	D1	1N4148
C11	330µF	U1	LM386
C12	680nF	Q1	2N3819
C13	270pF	Q2	BC109
L1	90µH - see text		
L2	90µH - see text		

source, but are only 75p each (plus nominal postage charge) and while writing this in early July 2011, I confirmed that there are a couple of hundred in stock (but you could wind your own - see later).

Generating the carrier

At the heart of any transmitter is the circuit (or circuits) which generate the carrier frequency. For stability reasons, most transmitters mix oscillators running at different frequencies to get the final carrier frequency. (OK, there are loads of exceptions to this, particularly in older or simple amateur radio equipment...) But in a very low power circuit we can get away with just amplifying the oscillator running at the carrier frequency. So what are our options?

Quartz crystals: If the frequency is not going to be changed, a crystal oscillator is by far the easiest to design. It is fairly immune to frequency drift and pulling by varying loads, and at room temperature a crystal oscillator running below about 5 MHz can be tweaked to within 10 Hz of the specified frequency - and usually much closer - thus virtually eliminating a heterodyne from a co-channel station if used on medium-wave.

Unfortunately, if you want a quartz crystal cut for a medium-wave channel, they have to be made to order costing £20 to £30. You can pick up cheap crystals that will oscillate somewhere on medium wave, but they are unlikely to be on channel. It's possible to get much cheaper crystals operating at higher frequencies and divide or mix them to operate on medium wave, but that significantly complicates the circuit.

Synthesizer: This is too complex for something as simple as this project, and adds significantly to battery-current drain.

VFO: A free-running L-C variable frequency oscillator is not ideal as temperature-related drift and FM-ing can degrade performance. But with careful design these shortcomings can be made negligible at frequencies below about 10 MHz – as demonstrated by the free-running L-C local oscillator in most domestic superhets.

Ideally the VFO should operate exactly on a channel so that the almost inevitable co-channel station at night does not cause a heterodyne. Unfortunately with a simple LC oscillator this isn't easy to maintain (hence the use of a crystal oscillator in the design mentioned above) and the MiniMod is likely to drift by just a few tens of Hertz for the first minute or so of use. Drift only becomes noticeable on an AM radio when it approaches hundreds of hertz.

In practice, once set up, the MiniMod signal should swamp all but the strongest co-channel stations, which you would avoid anyway.

The circuit

The construction method is not critical; Veroboard or other matrix boards will do. None of the component values are critical either, and plus or minus 20% will be near enough. However, C1, C2 and C13 should be close to the quoted values and be mica or polystyrene types to maintain temperature-related frequency stability. (The translucent polystyrene types often have one end slightly coloured. This indicates the outer foil connection and should be connected to the "most grounded" side of the circuit as it provides some self screening.)

Inductors L1 and L2 are both 90 µH variable inductors, supplied by Spectrum Communications (phone/fax: 01305 262250). These inductors are tapped at 25% from one end and have a low impedance secondary winding. The secondary is not used in L1 and the tapping is not used in L2. (One end of L1's unused secondary winding should be earthed to aid frequency stability.)

These inductors are compact and screened, but there is no reason why a keen constructor couldn't wind their own on a large ferrite bead, bit of ferrite rod or a toroid, although frequency stability is likely to be worse than the specified coils. (Full technical details of these coils available at www.spectrumcomms.co.uk/Spectrum%20Coils.htm)

The 2N3819 FET is widely available as is the BC109, although most general-purpose NPN silicon transistors will be suitable.

All set up to tune into something different...

The oscillator: This is a standard FET Hartley configuration and L1 sets the oscillator frequency.

Any oscillator should have a stabilised voltage supply to help maintain frequency stability. However, I found that the frequency shifted by only about 200 Hz between a supply of 4.5 and 12 volts. This is a much greater voltage range than will be encountered from a PP3 battery so voltage-related frequency drift renders a regulator unnecessary.

A voltage regulator may help smooth out any audio frequency ripple that could reach the drain of Q1 and cause unwanted frequency modulation. However, I found that a 330μF electrolytic capacitor, C4, with a 1k ohm drain resistor R3 did the same thing - another reason why a voltage regulator wouldn't present any advantages.

Theoretically, to fully isolate the oscillator, it should be followed by a buffer stage. This prevents modulation-induced impedance variations of Q2 from affecting Q1 and causing slight frequency modulation. In practice I found the amount of FMing to be barely detectable when listening on an SSB receiver and completely unnoticeable in normal AM.

Modulator: Although the modulated signal is mono, most sources will be stereo so a simple method of combining the left and right channels is required. (The proper way these days is to use op-amps, but that's not necessary here – I'm trying to keep this simple.)

Resistors R4 and R5 couple the left and right channels without directly shorting them together and R7 acts as the load replacing the low-impedance headphones the audio player is expecting to see. Capacitor C6 prevents any RF getting into the player. With such low power RF, decoupling here is hardly necessary, just good practice.

The signal from the player's headphone output is amplified by U1. The LM386 amplifier is designed for low-current battery use and will work down to a supply of about 4.5 volts. The output at pin 5 always sits at half the supply voltage, ensuring a symmetrical audio waveform. RF is prevented from getting back to the audio stages by C7.

RF output: The modulated DC output from U1 supplies the RF amp Q2 via current limiting resistor R8 through the low-impedance winding of L2. This simple arrangement only provides about 80% modulation (see photos), but as most simple envelope detectors start to distort at modulation depths much higher than this, it's not a noticeable disadvantage. Many broadcasters don't usually exceed 85 to 90% modulation either.

Transistor Q2 operates in class C and the modulated signal appears across the tuned circuit of L2 and C13. The antenna can be any thin insulated wire 50 cm to 2 m long. Any longer and it will affect the tuning range of L2, which is adjusted for maximum RF output.

I experimented with a number of ways of radiating the signal, including tuned loops of various sizes, but decided the L2/C13 arrangement was the most convenient.

The eagle-eyed will notice that there is no low-pass filter on the RF output. A single tuned circuit with reasonable Q such as this reduces harmonics significantly and since Q2 only dissipates about 20mW and the tiny antenna is much, much less than 1% efficient, I don't think we need to worry about the harmonics…

The circuit does not include any audio compression or audio-frequency tailoring. Compression makes the station sound "louder" and overcomes noise, particularly at the edge of a broadcaster's service area but requires complex circuitry to do well.

Frequency tailoring by medium-wave broadcasters restricts the higher modulating frequencies to prevent the station spreading to adjacent channels, usually boosting audio frequencies at about 2.5 to 3.5 kHz before cutting hard above about 4.5 kHz.

The signal from the MiniMod will be strong when placed close to the radio and the frequency response will be determined by the receiver's IF bandwidth. If your audio source has tone controls, you can use these, although increasing the audio player's output at frequencies beyond the receiver's IF pass band will not increase the treble content as heard on the radio. (The circuit's 6 db audio bandwidth approximately 20 Hz to 15 kHz)

Setting up

I would strongly advise that initial set up is done during daylight. The large number of stations which fade in after dark can make finding the signal a bit tricky, especially if L2 has not yet been peaked when the radiated signal may be quite weak.

With a non-metallic trimming tool (a match or cocktail stick cut to a fine wedge will do) screw the cores of L1 and L2 flush with the top of the formers.

Lay the antenna close to the radio; 50 cm of wire should be enough to start with. Initially set the volume from the audio player to about half way and connect its headphone output to the MiniMod.

Find the signal on the radio; this should be very roughly around the middle of medium-wave. If this is a clear spot on the dial, just peak L2 for strongest signal. If not, then find a clear spot on the dial and adjust L1 until you can hear the MiniMod. Peak L2 for the strongest signal; the peak for L2 is quite broad.

Note: The inductance range of L1 and L2 give a frequency range of about 900 kHz (cores flush with top of the formers) to 1600 kHz (cores screwed all the way down). This corresponds to about 330 to 187 metres. I'd recommend staying near the middle of this range if possible as although the two tuned circuits have very similar ranges, it is not exact. You may find that one end of the range of L1 might be just beyond the range of L2 so you won't be able to peak it. (If you want to shift the frequency range, increase or decrease the values of C1 and C13 by up to 50pF each.)

Lengthening the wire antenna up to about two metres will increase the range of the signal, as will connecting an earth (from a radiator pipe for example) to the negative battery connection. You will need to experiment a little with the proximity of antenna to the radio for the best results. Don't forget to give L2 a final tweak for maximum signal.

Things to look out for

After dusk, you may notice interference from stations that were inaudible during the day. If this happens, retune the MiniMod to a clear spot, move its antenna closer to the radio and/or adjust your player's headphone output level

Avoid the second harmonic of the receiver's intermediate frequency (e.g. 2 x 465 = 930 kHz) as you'll probably experience a nasty heterodyne.

If you have severe interference from the mains or nearby electronic devices, place the MiniMod's antenna as close to the antenna circuits of the radio as possible. In extreme cases, if the radio has an antenna socket, a direct connection via an isolating capacitor (say 0.01 μf) can be tried, but this may overload the receiver. Alternatively you could try pushing the insulated antenna wire into the antenna socket without making a direct connection.

Most miniature FM radios use the headphone lead as the receive antenna. If you connect one of these radios to the MiniMod to relay an FM station, it may not work.

Keep your audio player away from the radio as these devices can radiate interference from their electronic circuits through their unscreened plastic cases.

Do not set the headphone volume from your player too high as this will over-modulate the MiniMod and distort the signal. It should be just high enough to give a clear sound.