### Wireless broadcasters

One of the less pleasant recent hacker surprises is that most low-cost FM wireless broadcaster circuits flat out will no longer work. Older analog FM radios could be tuned anywhere across the entire band and had a very strong AFC or *automatic frequency control* circuit that would lock onto a non-standard signal and track it anywhere. But nearly all of today's digitally synthesized FM receivers (especially most car radios) absolutely *demand* that the transmitted signal be precisely locked onto one of the FM broadcast channels.

Designing any high-quality FM transmitter that is both ultra-stable and able to be rapidly and linearly frequency modulated gets tricky fast because you are asking for a circuit that both will and will not change its frequency. The "technically correct" high-end solution is to use an indirect circuit known as the *frequency lock loop*. The average output frequency from your transmitter gets divided down with a counter and compared against a crystal reference. An error signal is then derived phase-lock-loop style and used with varactor diodes to continuously force your transmitter back onto the correct frequency.

Hams have long chosen a simpler technique called *crystal pulling*. Your average crystal is *slightly* sensitive to reactive loading in a circuit. The rule of thumb is that you can pull a plain old crystal around *one-tenth percent*. But crystal pulling is usually highly nonlinear.

To pick up enough deviation, hams would start off with a low-frequency crystal and then multiply up into their final 145 megahertz—or whatever frequency range. Typical hams rarely concern themselves with any wide-deviation broadcast-quality audio. In fact, they are not allowed to do so.

Apparently both *Sony* and *Pioneer* have figured out how to linearly pull a special third-overtone HF crystal to *directly* let you do a full CD-quality FM stereo transmitter that is precisely locked onto the correct frequency. Sony's product is called the XA-7A, and Pioneer's is the CD-FM-1. While the intended use of those units is to let you conveniently add a CD player to your car radio, either one will apparently make up most of the critical circuitry for an excellent and very high-quality FM stereo wireless broadcaster. Dealer cost for the units is in the $42 range, and they seem to be easy and fun to hack. They offer both on-channel lock and near-broadcast quality. We will look at the *Pioneer* CD-FM-1 here.

Obvious uses for a short-range FM broadcaster include "Please buy my house" messages for drive-bys; baby sitting or handicapped monitoring; and cord-free audio for a teacher, a public speaker, or a video actor. But there are also zillions of non-obvious uses, including such things as getting data onto or off of a rotating shaft, and short-range rocket telemetry.

Limited-range and limited-power FM broadcasters are now generally allowed by the FCC, while the more powerful units have to meet specific licensing and certain type-approval requirements. More details on getting and meeting FCC specs appear in our *Hardware Hacker III* reprints. Both the unmodified *Sony* and *Pioneer* seem to have been created with full FCC compliance code in mind.

I could also see several *wired* or *semi-wireless* broadcaster applications that might use twin lead to route high-quality audio all over your plant or whatever. With wires, you could easily go several hundred feet without running afoul of FCC specifications, all the while avoiding the hum and noise problems of using "real" audio. And a whole new world of point-of-sight light-modulated FM data links is also newly opened up.

In their intended use, you unplug your car radio antenna, plug in the CD-FM-1, and then reconnect your antenna. A DIN-8 connector goes to your CD player, and the usual red wire goes to your +12-volt battery.

When your CD is turned on, its audio appears at 88.1 on your FM dial. All other stations are muted. That quickly and conveniently lets you use your existing car audio system without needing anything fancy in the way of rework or switches.

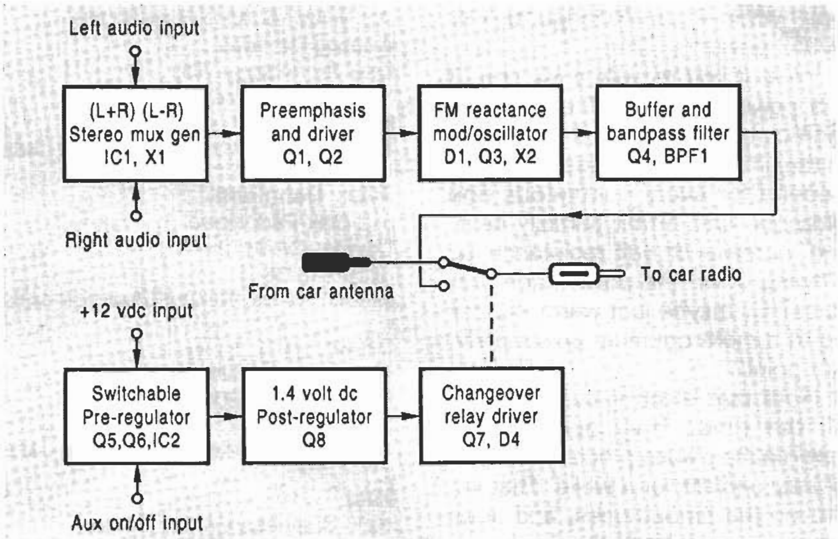



**FIG. 2—MOST LOW-END FM WIRELESS BROADCASTERS simply will no longer work because nearly all the newer synthesized receivers now *demand* precisely on-channel stations. The Pioneer CD-FM-1 (block diagram shown here) generates exact-frequency stereo FM signals. The CD-FM-1 is easily made wireless.**

A block diagram of this matchbox-sized module appears in Fig. 2, while an approximate and unofficial schematic is shown in Fig. 3. Because of the surface-mount parts used, certain component values are based only on my estimates. The exact circuit shown also might not be fully accurate.

At first glance, the circuit seems deceptively simple. But if you flip the board over, you'll find nearly a dozen more surface-mount semiconductors on the foil side. It is obvious that bunches of time and effort went into the design.

As with any circuit, you usually want to start off with your power distribution. The twelve volts from the car battery turned off and on by an auxiliary (AUX) logic signal. The power is applied only when your CD is to be used. The power switching is via input-switching field-effect transistor Q5 and series power driver Q6. Driver Q6 is followed by a two-volt regulator IC2, which in turn is followed by a *dynamic regulator* or *capacitance multiplier* at Q8. The post-regulator will obviously introduce a temperature drift that might or might not be intentional.

Several refinements in the supply switching include Zener diode D2 to prevent turn-on with a weak battery or during cranking. The network R27-C30 gives a slight turnoff delay to eliminate clicks or thumps.

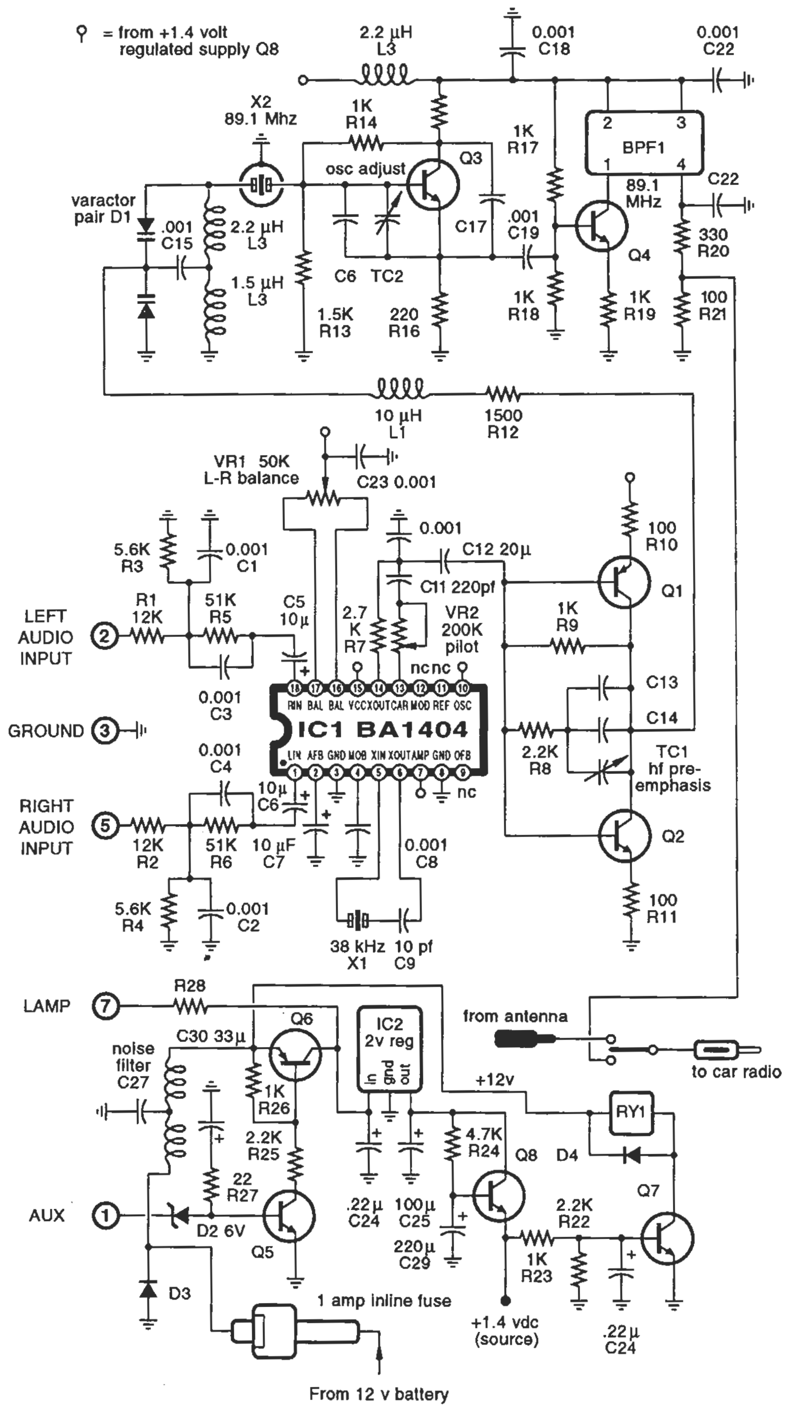
Except for that switchover relay, the rest of the circuit runs on the dynamically regulated 1.4-volt supply. Theoretically, a single AA cell could be used instead.

The heart of the circuit is the great *Rohm* BA-1404 FM stereo broadcaster chip that we have looked at in the *Hardware Hacker II* reprints. Only this time, the internal RF transmitter circuitry is *not* used and gets very carefully deactivated. A 38-kHz signal (X1) is needed to modulate the incoming audio and to create the 19-kHz pilot signal. Control VR1 adjusts your balance, and VR2 sets the 19-kilohertz pilot level.

The multiplexed audio output is added to the pilot and routed to a combination driver and pre-emphasis network via Q1 and Q2. The amount of high-frequency pre-emphasis is adjusted by TC1.

The linear and broadband "crystal puller" is an interesting reactance modulator scheme using a pair of varactor diodes at D1. A simplified circuit of the modulator appears in Fig. 4. What you've got is a crystal in series with the parallel resonant circuit "A," which is, in turn, in series with a second resonant circuit "B."

Tank "A" is tuned well *below* the crystal's parallel resonance and will normally appear as a high *inductive* reactance. Tank "B" is tuned *above* the crystal parallel resonance and will appear as a *capacitive* reactance. In the absence of any audio




WARNING: Be sure to current limit the AUX input with an external 1K resistor!

**FIG. 3—APPROXIMATE SCHEMATIC of the Pioneer CD-FM-1. While intended as a CD-audio-to-car-radio adaptor, this module can easily become a highly stable and on-channel FM stereo wireless broadcaster. Applying +12 volts to the AUX input activates the module.**

modulation, the reactances will cancel, and the series combination of the crystal and the two tanks becomes a high-impedance open circuit.

Those varactor diodes act as electronically variable capacitances that raise or lower the tank frequencies. On positive modulation swings, both tanks *increase* their resonant frequencies; on negative swings frequencies decrease.

The final result is a reactance frequency modulator whose resonant frequency is set by the crystal but it is rapidly shiftable either way by the multiplexed audio. Usually a frequency change varies as the *square root* of a capacitance change. But, because a *pair* of varactor diode capacitors is changing, the resonant frequency changes *linearly* with the modulation input.

At any rate, Q3 is a *Pierce*-style oscillator that can oscillate at the frequency determined by the highest impedance sum of the crystal's third overtone resonance and the reactance modulator tanks. A frequency of 88.1 megahertz is used in my particular sample, with a final trim given by TC2.

The fundamental crystal frequency is way down at 29.7 megahertz, but the oscillator tries its best to run at 88.1. The resultant waveform thus has some uneven subharmonic lumps.

It is very important to keep the loading on any FM oscillator constant, especially when using an overtone crystal. So, a buffer and driver transistor follows at Q4. That in turn drives a special bandpass filter (probably a surface acoustical wave, or a SAW device) to eliminate any subharmonics and out-of-band harmonics. Only the crystal's third overtone at a frequency of 88.1 MHz is allowed through the filter.

Even with the attenuation through the bandpass filter, the output signal is still too strong to directly couple into an FM receiver's antenna, so it is further attenuated by R20 and R21.

Recall that the supply power is turned on only when you want to listen to your CD player. When the 1.4-volt DC supply voltage is present, relay-driver Q4 and spike-suppressor D4 pull in the relay, connecting the RF-converted CD audio directly to your auto-radio antenna input. At the same time the antenna is disconnected to prevent any back radiation or unintentional broadcasting. You do, of course, also have to pushbutton select 88.1 MHz on your car radio to listen to the CD audio.

Once again, this description is for the FM-CD-1. The XA-7A uses a somewhat different circuit that we might look at in a future column if there's enough interest.

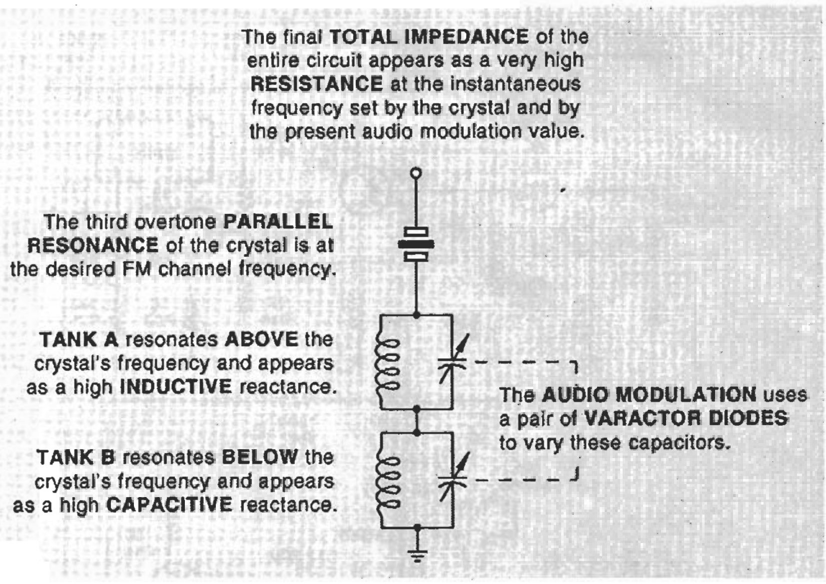



**FIG. 4—SIMPLIFIED SCHEMATIC of the linear reactance modulator.**

## Hacking the CD-FM-1

In the absence of a CD player, the CD-FM-1 can be activated by connecting the AUX input to the +12-volt supply. Your left and right audio inputs are normally at "line" level; additional gain will be needed for most microphones. Any and all audio connections must be shielded.

The antenna changeover relay might be optionally defeated by shorting R23. Supply current is 30 milliamps with the relay active and 17 milliamps with it defeated. Another four milliamps can be saved by disconnecting the AUX input and shorting the collector to emitter on Q6. Nearly another milliamp can be saved by removing R22. The remaining power needed by the "useful" part of the circuit is then 1.4 volts at eleven milliamps, or something around fifteen milliwatts.

With those power reductions, you could probably substitute an ordinary 9-volt transistor battery for your 12-volt supply. But be sure to turn the power off when you are not using the transmitter.

Theoretically, you might want to replace the dynamic regulator Q8 and substitute a single AA cell instead. A bypass capacitor or two would also be a good idea if you try that. One way or another, though, you can easily get the circuit down into the millipower range but not the micropower range.

A possible antenna takeoff point for any low-level direct-broadcasting experiments seems to be the collector of Q4. Figure 5 shows how to route a 30-inch antenna wire through a grommet in the case. I got a 50-foot useful range with a good car radio that way. Be sure to insulate the wire tip to prevent possible shorting of the DC supply or damaging of the filter. A far cleaner but weaker takeoff point would be the pin-4 filter output.

While the BA1404 supply voltage can be raised as high as 3 volts, doing so may change the performance of the reactance modulator.

The best way to increase the range is to improve the antenna on your receiver. Be sure to connect a good receiving antenna and disconnect any cable connections. Experiment with the antenna orientation; vertical might be best for car radios and horizontal might work out better for a home hi-fi.

The range can also be improved by placing a ground plane, such as a grounded cookie sheet (or preferably something bigger), under your transmitter. That could give you a hemi pattern with double field strength.

A directional receiving antenna, such as a correctly cut Yagi, can also dramatically improve your range.

Note that lower power plus good antenna matching and orientation will give you vastly more range than will high power and poor or improperly aligned antennas.

While there is that extra booster amplifier remaining unused in the BA1404, it might be tricky to access and still have it remain stable. An external boost circuit could also be built using a 2N918 transistor or something similar. That would best be done in a separately shielded and a properly decoupled box. *Do not, under any circumstances, attempt to amplify the unfiltered output.* Doing so will create unacceptably strong outband signals especially at 29.7 megahertz.

What can you get away with in the way of increased power? Any boost at all gets you into a legal gray area. But, as a practical matter, if your DC input power to your boost stage is under 50 milliwatts, and if nobody complains, and if your total useful range is well under a hundred feet, and if you use the transmitter yourself rather than selling it to someone else, you can probably get away without any serious problems or hassles.

On the other hand, using one of these as a predriver to broadcast heavy metal to your entire college campus is a very big no-no.

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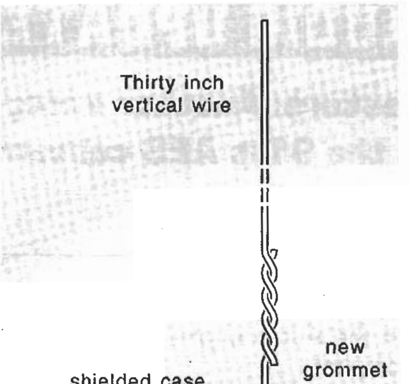


**FIG. 5—AN ANTENNA CAN BE ADDED as shown to the CD-FM-1 for your initial short-range FM broadcasting experiments. Be sure to insulate the far end of your coupling gimmick. Experiment to get the best length and orientation.**