# 2-metre band converter

## *capture 144 MHz DX signals*


**If you have a general coverage shortwave receiver available and would like to extend its frequency range with the two-metre amateur radio band, the present design is for you. Easy to build from low-cost parts, the converter should make an excellent entry-level project for budding radio enthusiasts. The converter is also a prefect companion to the general-coverage multi-mode SW receiver described last year in this magazine.**

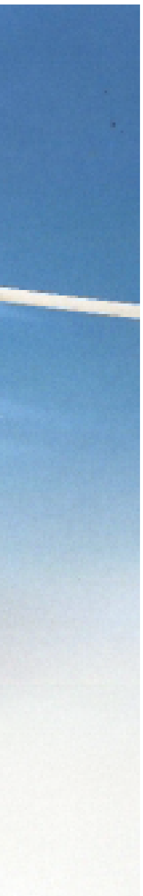
Design by G. Baars

The 2-metre radio amateur band is still the most popular band worldwide. It extends from 144 to 146 MHz in most European countries, and from 144 to 148 MHz is some other countries like the U.S.A. and Australia. Traditionally, the band is associated with short-range communication over distances of up to 50 miles or so using narrow-band frequency modulation (NBFM) and power levels up to about 50 watts. This is also called 'local traffic' by some radio amateurs. Thanks to the relatively short antenna lengths and general profusion of cheap Japanese high-tech rigs and converted PMR kit, the 2-m band is also the place to be for mobile and portable communication, witness the presence of amateur-built and operated repeater stations in many countries and areas.

The lower part of the 2-metre band is reserved for narrow-band modes like CW (Morse) and SSB (single-sideband). Mainly because of the smaller bandwidth and resultant better signal-to-noise ratio for weak signals, these modes offer far greater ranges than NBFM. The 'sound' of the band section between say 144.000 MHz and 144.400 MHz is therefore not unlike that of a shortwave band like 10 metres (28 MHz). Provided you use a good directional antenna (like a yagi) you should be able to pick up the CW idents of low-power beacons as well as CW and SSB signals from stations far beyond the range of NBFM.

## Why a converter?

Many beginners to the radio hobby start will start out with a second-hand shortwave receiver. This will typically be a general-coverage type for CW/USB/LSB/AM/RTTY reception between 150 kHz and 30 MHz. The Yaesu FRG-7 is an excellent example of such a receiver, and although its design is 25 years old, it is still in popular demand in the radio amateur trade. The same beginners will also lack the funds (and a licence) to buy an all-mode VHF transceiver, so why not add 2-metre band reception to the available short-wave receiver? With some luck, this has an NBFM mode, too, so you can also listen to 'local' traffic and get to know the hams in your area.



It should be noted that reception of DX (long-distance) signals in the 2-metre band requires a good directional antenna with a gain of at least 10 dB and low-loss coax cable to the receiver (or converter) input. Whatever low-noise pre-amplifier you may have in mind, experience shows that it is beaten hands down by a good antenna in an elevated position.

Following a well-established tradition in ham radio, the present converter mixes the 2-metre band signals down to the 10-metre band (28.0-29.7 MHz).

## How it works

The circuit diagram of the 2-metre band converter is given in **Figure** 1. As you can see it employs only five active components, and these are all of the common or garden variety.

The design consists of four sections, a local oscillator, a mixer, an input stage, and an output stage which will be discussed separately below.

**Local oscillator (LO)**

Transistor T1 and quartz crystal X1 are configured as an oscillator with an output frequency of 38.667 MHz. The crystal operates in third-overtone mode. Trimmer C1 is available to net the oscillator. The oscillator output signal is fed to frequency tripler T2 whose collector circuit is tuned to 116 MHz by L3 in combination with trimmer C7. The local oscillator signal has a level of about 100 mV peak to peak and is inductively coupled (via L4) to the mixer.

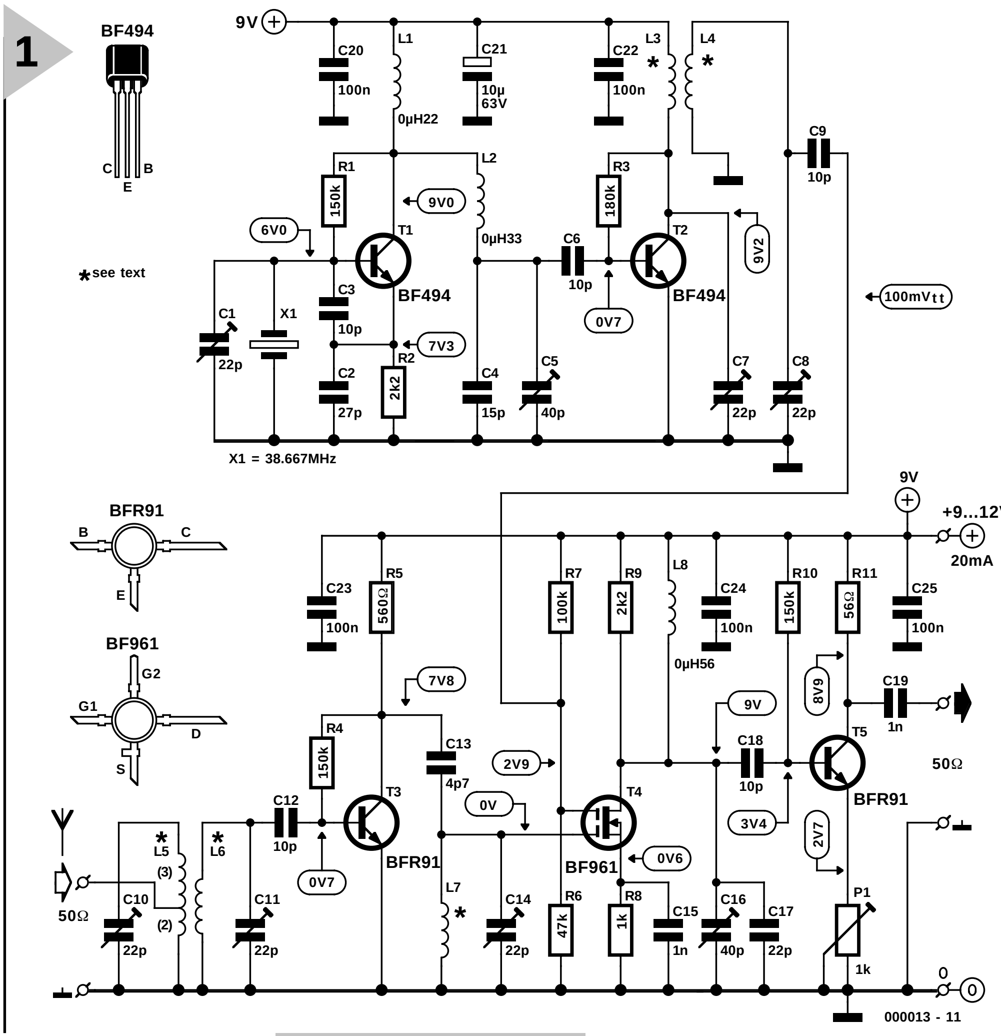



*Figure 1. Circuit diagram of the 2-to-10-m converter.*

**Mixer**

The mixer in the converter is a type BF961 dual-gate MOSFET, T4. The local oscillator signal is applied to gate 2 (G2) and the RF input signal, to gate 1 (G1). Note that G2 is held at a fixed potential of about 2.9 V by R6-R7, while G1 is dc-wise at ground potential. This is the traditional configuration, with the G2 resistors determining the conversion gain. The mixer products are available at the drain of the BF961. These products are, in principle: 144 + 116 = 260 MHz, 144–116 = 28 MHz and the LO signal residue at 116 MHz. The combination L8/C16/C17 is tuned to 28.8 MHz and serves to suppress the 116 MHz LO component — given the frequency difference between these components sufficient suppression is not hard to achieve.

**Input stage**

The signal from the 2-metre antenna is inductively coupled to the base of T3, a low-noise VHF/UHF transistor type BFR91. The input inductor pair L5-L6 is accurately tuned to 144 MHz by trimmers C10 and C11. The input bandfilter serves to suppress image frequencies at 116–28 = 88 MHz and at the same time match the transistor to the cable impedance of 50 Ω. The amplified signal is capacitively coupled to gate 1 of the mixer via C13.

**Output stage**

The main function of the driver stage around T5 is to provide a good match to the receiver input (50 Ω). The gain of this stage is made adjustable with preset P1 to ensure that no overdriving occurs with sensitive shortwave receivers.

The converter is powered by a regulated and well decoupled supply with an output of between 9 and 12 volts. Current consumption will be of the order of 20 mA.

## Construction

The converter is built on a single-sided printed circuit board of which the design is shown in Figure 2. This board is available ready-made through the *Elektor Electronics* Readers Services.

Before you start soldering away we recommend you make inductors L3-L7. This is not at all difficult. Take a pen or a drill bit with a diameter of 4.5 mm

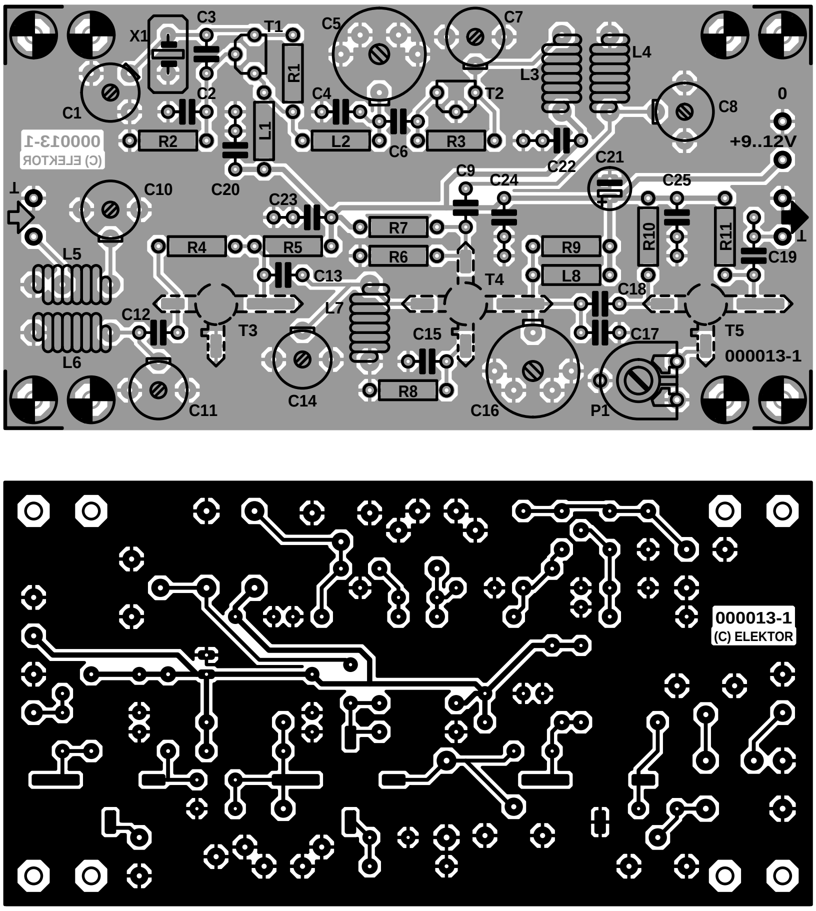
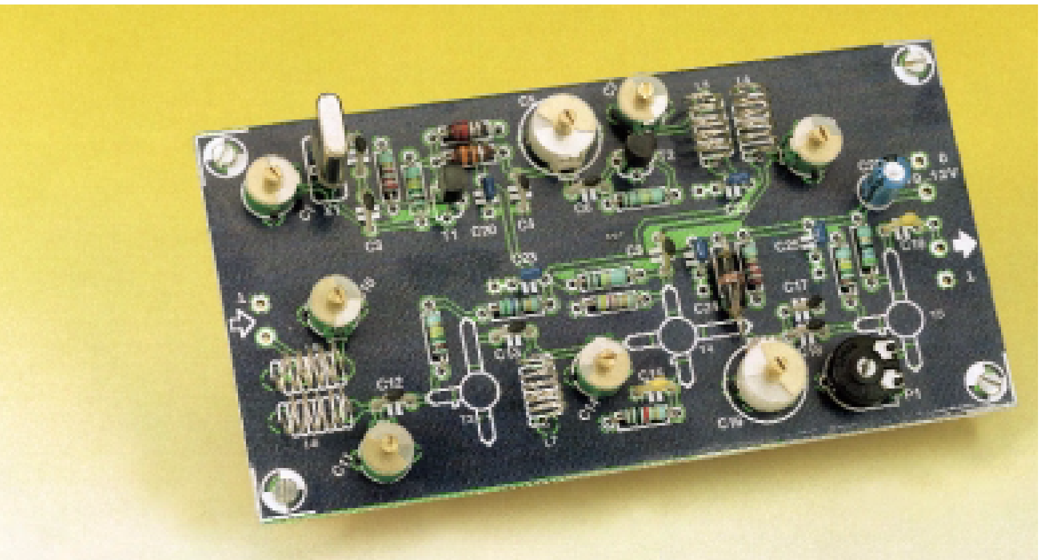



*Figure 2. Copper track layout and component mounting plan of the single-sided PCB. Three transistors are mounted at the solder side!*



**COMPONENTS LIST**

**Resistors:**
R1,R4,R10 = 150kΩ
R2,R9 = 2kΩ2
R3 = 180kΩ
R5 = 560Ω
R6 = 47kΩ
R7 = 100kΩ
R8 = 1kΩ
R11 = 56Ω
P1 = 1kΩ preset H

**Capacitors:**
C1,C7,C8,C10,C11,C14 = 22pF trimmer
C2 = 27pF
C3,C6,C9,C12,C18 = 10pF
C4 = 15pF
C5,C16 = 40pF trimmer
C13 = 4pF7
C15,C19 = 1nF, raster 5mm
C17 = 22pF
C20,C22-C25 = 100nF ceramic
C21 = 10μF 63V radial

**Inductors:**
L1 = 0.22μH miniature choke
L2 = 0.33μH miniature choke
L3-L7 = 5 turns silver-plated wire, dia. 0.8mm (SWG20), internal diameter 4.5mm, length 10mm
Distance between coupled inductors: 1mm, tap at 2 turns from ground side
L8 = 0.56μH miniature choke

**Semiconductors:**
T1,T2 = BF494
T3,T5 = BFR91
T4 = BF961

**Miscellaneous:**
X1 = quartz crystal 38.667MHz (3rd overtone) (Mainline, tel. 0870 2410810)
PCB, order code **000013-1** (see Readers Services page)
Case: e.g. Hammond 1590B 56×107×25 (inside dimensions)

and wind 5 turns of SWG20 (approx. 0.8 mm dia.) silver-plated wire around it. Then stretch the turns evenly until the coil has a length of about 10 mm. Only on L5 you 'tap' the inductor at 2 turns from the side you want to connect to ground (look at the component overlay). The tap is made by means of a small piece of bare wire. Make sure it does not short-circuit the adjacent turns! Coupled inductors L5-L6 and L3-L4 should be spaced 1 mm apart.

Next, fit all the parts on to the board, except transistors T3, T4 and T5. Remember, careful and accurate soldering work will be rewarded with a circuit that works spot-on.

To keep parasitic capacitance as small as possible, **the BFR91 and BF961 transistors are fitted at the solder side of the board. This is indicated by their dashed outlines on the component overlay**. Look very carefully at the orientation aids on these transistors to make sure they are mounted the right way around. On the BFR91, the collector is the longest pin; on the BF961, the source has a small tab and the drain is the longest pin.

The completed board has to be fitted in a metal case. For our prototype, we used a small diecast case from Hammond. The converter RF input and output may be BNC or SO239 style sockets, depending on what you have available. The connections between the sockets and the relevant PCB pins should be made in coax cable, for example, RG174 or RG58.

## An adjustment tool

We are sure that the simple RF probe shown in **Figure 3** will pay dividends in adjusting RF circuits. Build it and you will wonder how you ever did without it.

The probe consists of an aluminium pen case (a felt pen, cleaned out, of

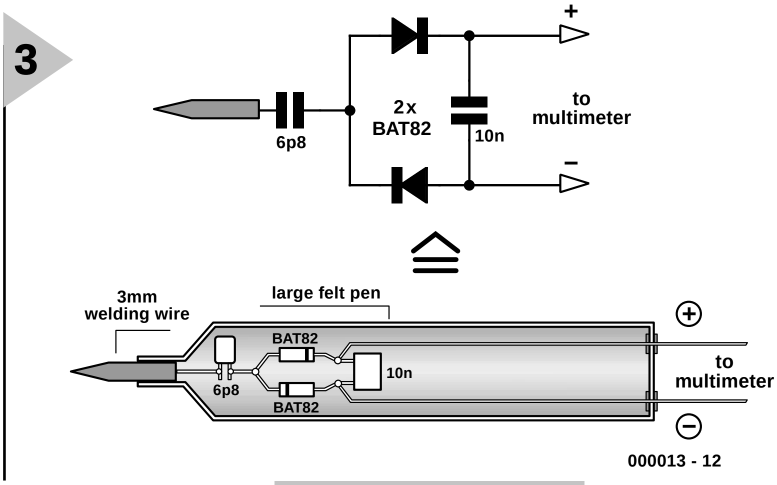



*Figure 3. Build this simple RF probe and adjusting the converter will be a breeze.*

course) in which a small diode detector is housed. The end of the copper or welding wire is carefully filed down to give a sharp tip. The choice of diode is not critical. While SHF diodes like the 1S99 will enable measurements well into the GHz range, the run-of-the-mill BAT82 will be fine for VHF circuits like the present converter.

The probe is only intended to give relative indications, providing an easy means to 'peak' inductors on their resonance frequency. It will only lightly load the tuned circuit and does not require a ground connection. The output voltage is fed to the inputs of a voltmeter — preferably analogue so you can see the 'trend'. In this case, needle movement on an antique moving-coil meter is rather more useful than rolling digits on a DVM.

## Adjustment

Start by setting all trimmers on the board to full mesh, except C1, which is set to mid-travel. Connect the converter to the receiver and switch on the power supply. Set P1 to the centre of its travel. Measure the current consumption. If it as expected, proceed with the adjustment procedure described below. "Hot" means carrying RF, "Cold" means not carrying RF, i.e., ground or positive supply. "Peak" means adjust for maximum reading on the voltmeter connected to the probe, or for maximum S-meter reading on the receiver. In case of the probe, the absolute value you measure is irrelevant, it's the peak you should be looking for.

1. Put the probe tip on the hot side of C5 and adjust this trimmer for maximum reading on the voltmeter.
2. Connect the probe to about 1 turn from the cold side of L3 and peak C7. You want the first peak starting from fully meshed. If not, you tune to $f_{osc} \times 4$ instead of $f_{osc} \times 3$.
3. Connect the probe to 1 turn from the cold side of L4 and peak C8. Use the first peak starting from fully meshed. If not, you tune to $f_{osc} \times 4$ instead of $f_{osc} \times 3$.
4. Set C10, C11 and C14 to half mesh.
5. Tune the receiver to 28.800 MHz and adjust C16 for maximum noise.
6. Ensure that a relatively strong input signal is available on a frequency between 144.800 and 145.000 MHz (RF generator or ask a local radio amateur). Peak C10, C11 and C14 for best reception. Reduce the input signal as required to ensure you can always find a peak.
7. Adjust C1 so that the frequency readout on the receiver matches the signal frequency, for example, 144.800 MHz = 28.800 MHz.
8. Remove the input signal and adjust P1 so that the S meter on the receiver just starts to deflect.
9. Tune to a weak signal in the 2-m band and carefully adjust C10, C11 and C14 for highest S-meter indication.

That concludes the adjustment of the converter.

## Weather-satellite band

By changing the LO injection frequency to 109 MHz, it should be possible to use the converter for reception of low-orbiting weather satellites in the 137 MHz band. A quartz crystal of 36.333 MHz (again, 3rd overtone) is then required, as well as readjustment of all trimmers for the slightly lower frequencies.

(000013-1)

## Band plan for 144–146 MHz (IARU recommendation)

***144.000 – 144.500 MHz***

*Reserved for DX traffic. Some important sub-bands:*

| | |
|---|---|
| *144.000 – 144.025:* | *EME (earth-moon-earth or 'moonbounce')* |
| *144.050:* | *CW calling* |
| *144.100:* | *Meteor scatter in CW* |
| *144.150:* | *CW DX* |
| *144.300:* | *SSB calling* |
| *144.400 – 144.490:* | *Beacons* |
| *144.490 – 144.500:* | *Beacon guard band, no transmissions* |

***144.500 – 144.800 MHz***

*All modes, including*

*144.500 SSTV calling*
*144.600 RTTY calling*
*144.700: FAX calling*
*144.750: ATV calling*

***144.800 – 144.990 MHz***

*Digital modes (Packet Radio)*

***145.0000 – 145.1875 MHz***

*Repeater input frequencies (12.5 kHz raster, shift 600 kHz)*

***145.2000 – 145.5875 MHz***

*Simplex channels, FM, 12.5kHz raster.*

***145.6000 – 145.7875 MHz***

*Repeater output frequencies (12.5 kHz, shift 600 kHz)*

***145.8000 – 146.0000 MHz***

*Satellite services*