Adventures in optical communication

Part 2 – SSB via light.

PHOTO 7: Linear transverter (built and photographed by Rob, M0DTS).

RECAP. Last month we looked at some simple CW and voice transmitting and receiving equipment capable of some tens of kilometers range on AM and FM. Then I wondered what advantage, if any, might be gained by going to SSB. This mode is paramount for long distance voice communication over most, if not all, amateur bands where it is allowed, so why not on light?

TRANSVERTER. The thought of building stand-alone systems for receive and transmit was eclipsed by one of those eureka moments: why not build a transverter? It occurred to me that I could use all of the gain and signal processing power of a small HF amateur radio transceiver such as my existing FT-817, converting the HF signals to light and vice versa. Actually, there was a bit more fun in it than simply that. Gordon, G8PNN, Brian, G8KPD and I have made a large number of transverters in the past, for every amateur band from 70cm up to 9cm. In addition, Gordon has a whole array of modern transverters up to 10GHz. The thought of him operating yet another in a long line of transverters was appealing.

Since we were already operating on 20kHz PWM AM and 25kHz FM, thoughts turned to the possibility of sending and receiving single sideband (or any other mode for that matter) on around the same frequency. Crystals for 3.58MHz (actually 3.579545MHz) are readily available, enabling the 80m band to be used for the intermediate frequency. We have ended up using 3.605MHz RF, thus producing or receiving an optical signal around 25kHz. It's sort of radio over light. It even looks and feels like you are operating a real radio when making optical contacts!

CIRCUIT DESCRIPTION. The transverter circuit is shown in **Figure 6**. A relay switches the HF transceiver between the Rx and Tx paths in the transverter (via resistive attenuators). The transmit attenuator reduces the 0.5W output from the transmitter to a few millivolts. This signal is mixed with the 3.58MHz local oscillator signal in the MC1496 balanced mixer to provide the 25kHz signal. This is amplified and low pass filtered by a NE3354 opamp (which also gets rid of the 7.2MHz mixer product) and then fed to the gate of a power MOSFET. The MOSFET has adjustable bias via R28 to set the quiescent gate voltage (and hence LED idling current). The LED and resistor are contained in a separate box (the transmit head, described later), mounted at the focus of a lens in a similar manner to the transmitters described last month.

On receive, the amplified 25kHz signal from a receive head (of which more later) is connected to the input of the mixer, which up-converts the signal to the 80m band thanks to the 3.58MHz local oscillator. The output of the mixer is switched to an attenuator to protect the HF transceivers front end. (The attenuator also protects the mixer against inadvertent transmission into the mixer output if the PTT fails). The local oscillator can be heard at a low level on the HF receiver if you tune down to the region of 3.58MHz. It is not strong enough to de-sense the receiver if you keep at least 20kHz away from it.

This linear transverter it is useable on any mode (although FM and SSB are best) and on a range of frequencies. 3.6MHz RF gives 20kHz optical; 3.65MHz gives 70kHz and so on. Lower frequencies should be better because they are less demanding of the electro-optical system. We have kept to frequencies around 3.605MHz (25kHz optical).

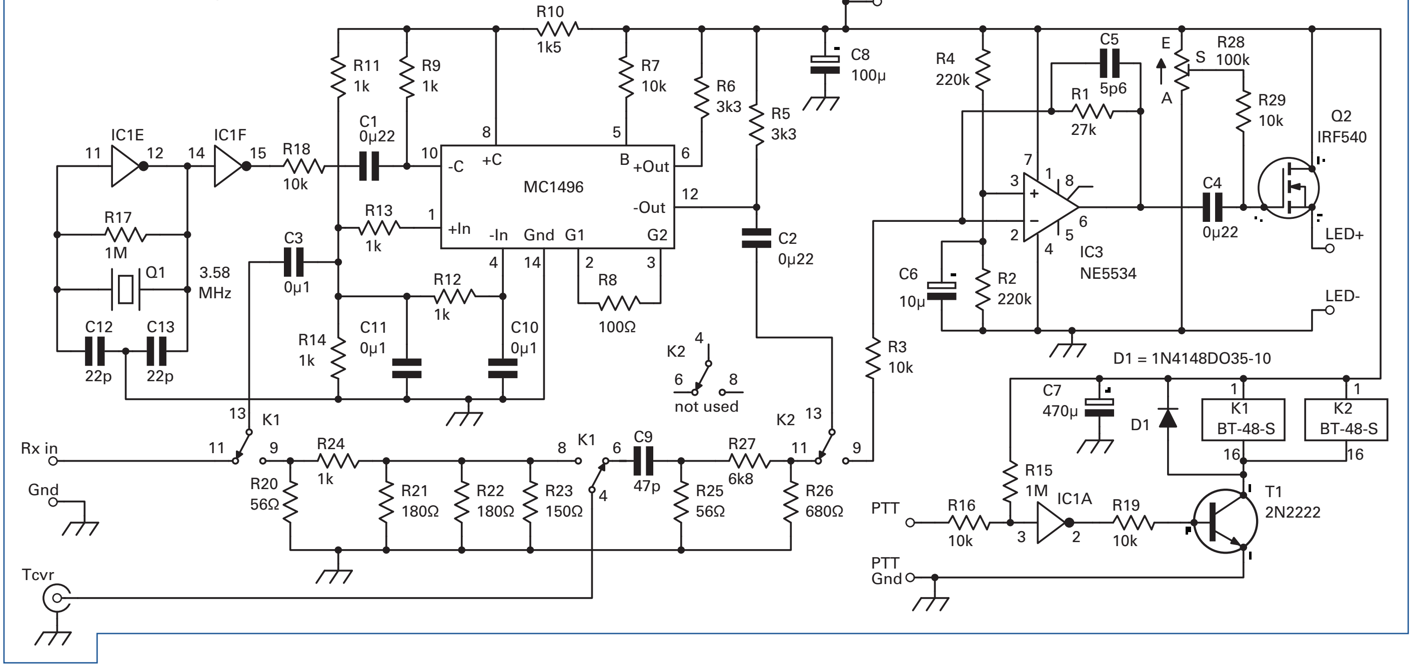
The prototype transverter PCB and overlay are shown in **Figures 7** and **8**. Note that the board should be double sided – the top is a ground plane that doesn't require etching. After you drill the board, identify all the ground connections and mark them (a marker pen pressed against the holes will usually be visible form the other side). Then turn the board over and, using a hand-held drill bit of about 3mm, clear the copper around the non-earth holes (eg the diode in the foreground of Photo 1). When you populate the board, solder all earth connections on both sides of the board (eg the four resistors near the middle). This will result in a good quality of screening.

SETTING UP. Before connecting power for the first time, turn R28 so the wiper is on the negative side (fully anticlockwise if you're using my PCB). Check the board current consumption – it should be around 20mA at 12V. Connect the LED head and, while monitoring current drawn, turn up R28 until the supply current is about 100mA more than you started, eg 120mA. This is akin to the bias setting on a conventional solid-state linear amplifier. It also gives adequate light for a distant receiver to line up on. Surprisingly, it is also left on when switched to receive, giving the distant station something to aim at.

OPERATING PRINCIPLE. It is easy to imagine what happens to an FM signal on transmit through the LED: the MOSFET is effectively in Class D and being driven hard, switching frequency modulated pulses to the LED at around 25kHz.

I had problems at first envisaging exactly what was happening with a single sideband signal, as only half of it will be conducted by the LED. This must be a bit like putting a

FIGURE 6: 3.5MHz to 25kHz transverter circuit diagram.



rectifier diode in series with your HF antenna! Only the positive half of the sideband signal gets converted into light (the LED is a diode after all). These half-signal pulses travel to the distant receiver. If you could pick this up directly, without a tuned circuit at signal frequency, it would sound like the most awful, overdriven distorted signal you have ever heard on 20m during a contest. But it does not sound distorted at all on an HF receiver because the tuned circuits in the receiver restore the waveform due to the flywheel action of a high Q tuned circuit. Actually, something similar happens inside a single device class B linear amplifier, where the transistor amplifies only the positive half of the signal and the negative half is generated by the inductances in the circuit, so a complete signal is created.

Unlike many other transverters, there is nothing to tune up or adjust other than the LED bias pot. Most of us who have built this have not even padded the crystal down to its design frequency (although there are spaces for capacitors on the board for this), just leaving it about 2kHz high. Do not exceed the LED current ratings. By monitoring the total transverter current, you can keep an eye on the average current through the LED. I have installed a 1A fuse in the power supply line and blown it several times on speech peaks.

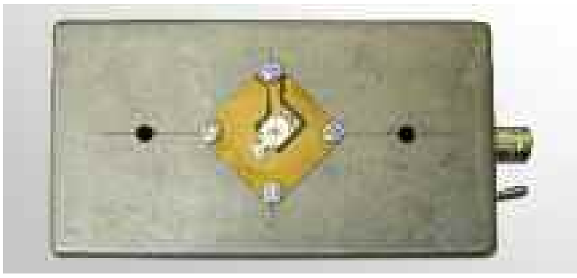


PHOTO 8: Power LED on transmit head.

My thanks to Rob, M0DTS who, in producing his version of my design, tidied up my circuits and photographed his version for this article.

TRANSMIT HEAD. The transmit head consists of a power LED and current limiting resistors mounted on and in a diecast box. **Figure 9** shows the circuit diagram. In normal use the QRO switch is left open. When using SSB it is possible to close the switch, which lets a lot more current flow through the LED LED on speech peaks. Do it at your own risk – it only gives about one extra S-point and I've blown several LEDs this way. Trying it on FM or CW is almost certain to blow the LED.

The LED is mounted on a 25mm square piece of 0.4mm fibreglass PCB on the base of the diecast box (**Figure 10**). Power LEDs get quite hot so it's important to use heatsink paste between the LED and the board and again between the board and the box, which acts as a heatsink. Do not use normal-thickness PCB! I put the two power resistors in the box and used a BNC socket for the drive connection. The box is mounted on a pipe-stop end with a central hole cut in it, then placed at the focus of a lens as described last month.

I used an Osram Golden Dragon LR W5SM HYJY-1 LED, RS part number 665-6189. It is quite important that you use this one because, although many others will work on transmit, next month I will explain how to make this particular LED also work as a photodiode on receive.

LATEST AND BEST FRONT END. Figure 11 shows the best front end I have made to date (and there have been seven in all). It is closely based on a design by Clint Turner, KA7OEI that I found on his website. I have altered the

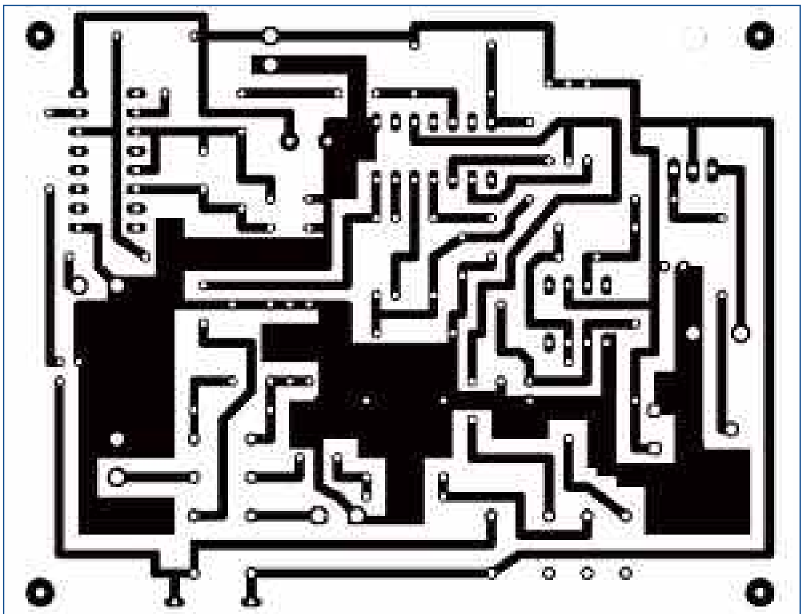


FIGURE 7: Transverter PCB foil pattern, full size.

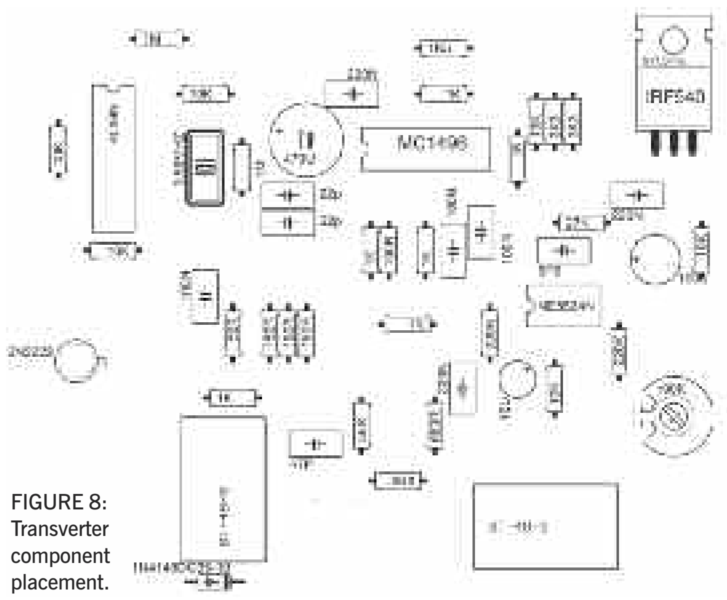


FIGURE 8: Transverter component placement.

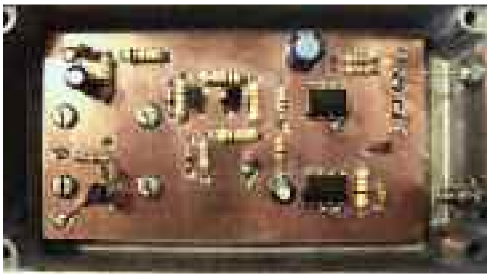


PHOTO 9: Receive head.

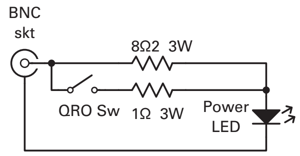


FIGURE 9: Circuit diagram of the transmit head.

first stage to be a reverse biased SFH2030 photodiode RC coupled to the gate of the FET. The relatively elaborate bias circuit is to make best use of the FET's low-noise performance. I also removed some of Clint's low pass filtering; the circuit now responds up to about 100kHz. T3 forms a cascade amplifier with the FET while T4 controls the FET drain current. The two low noise opamps provide further gain.

This circuit is so exquisitely sensitive that there is no alternative to a diecast box for shielding: even the power is fed down a shielded cable from the transverter. I use a 3.5mm stereo jack plug, socket and screened cable to bring power in and take the signal back to the transverter.

The SFH2030 photodiode just peeps out of a 6mm diameter hole in the box. This is normally placed at the focus of a lens on a pipe end cap, drilled as before. Any daylight reaching the photodiode will vastly increase its noise output so, while testing, I keep the head face down on the bench. Sliding it slowly to the edge of the bench instantly reveals when the tiniest amount of light enters because the noise level rises so much. You end up skulking around in the dark with this one! Without a lens, this head gives a noticeable increase in noise from moonlight and, with a lens, Jupiter and the brighter stars are easily detected.

Photo 9 shows the completed receive head, with the PCB foil pattern and overlay in **Figures 12** and **13**. As with the transverter, the PCB is double sided for screening; use the same drilling technique.

Next month I will finish off the series with a desktop test beacon, my mammoth 20W outdoor beacon and the LED transceiver that I hinted at earlier.

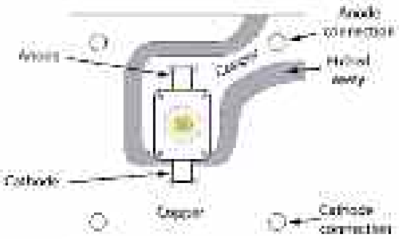
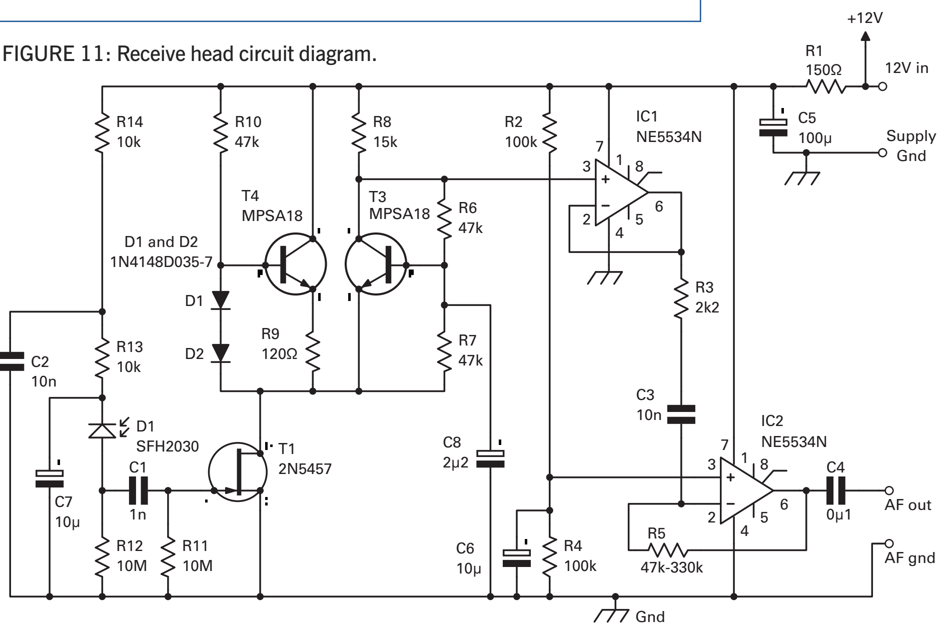


FIGURE 10: How I mounted the power LED.

FIGURE 11: Receive head circuit diagram.



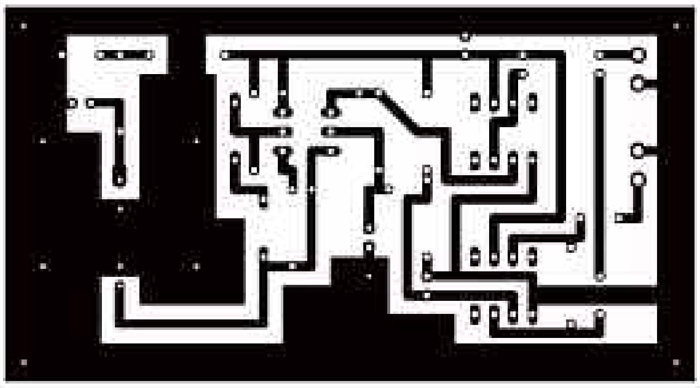


FIGURE 12: Receive head PCB foil pattern, full size.

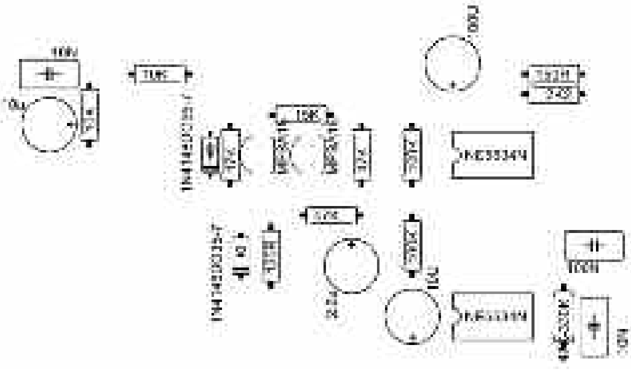


FIGURE 13: Receiver head component placement.