The 144MHz Anglian 3 transverter

A high performance 144/28MHz transverter

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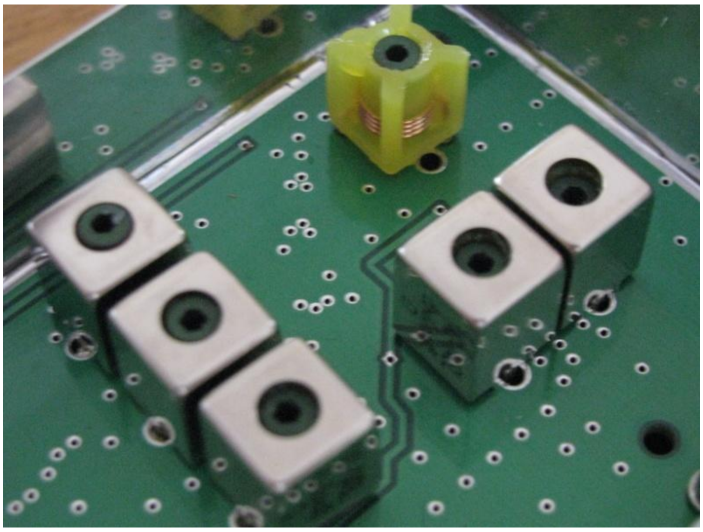


Introduction

Anglian 3 is an update to the 144MHz Anglian 2 transverter. The Anglian 2 is no longer available. Unlike the assembled-board Anglian 2 kit, the Anglian 3 is available as a kit of parts or PCB only.

This article is a technical description of the 144MHz Anglian 3 transverter. A separate, comprehensive, Assembly Manual, with overlays and a component list, is available on my web page.

Anglian description

The Anglian 144MHz transverter converts 28 to 30MHz transmit signals to 144 to 146MHz. On receive 144 to 146MHz signals are down converted to 28 to 30MHz. Due to the large number of component changes that would be necessary to use the transverter with an alternative IF, such as 21 or 14MHz, this is strongly discouraged. Table 1 shows the measured performance of the Anglian 3 transverter. You will notice that this is similar to the Anglian 2.

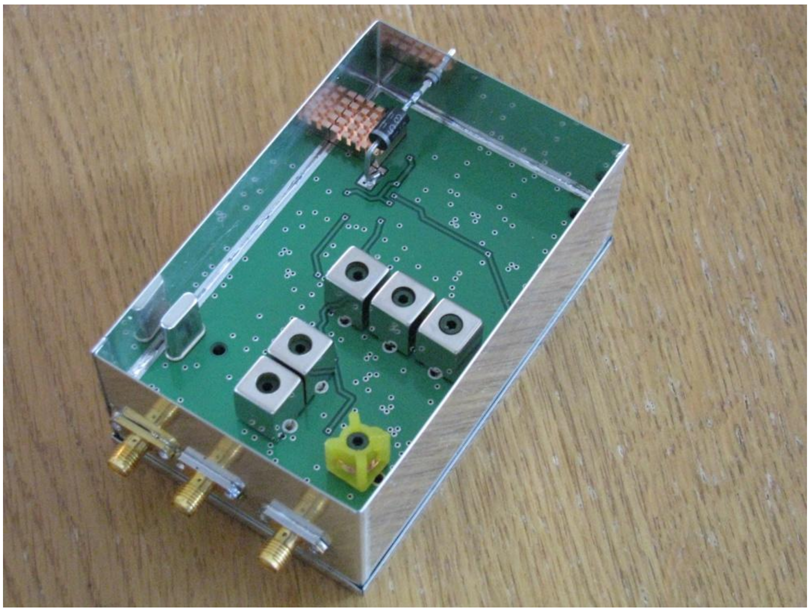
Parameter	Performance
Receive converter	
Noise figure	1.6-1.8dB
Gain	24-25dB
Input third order intercept (IIP3)	+0.5 to +1.5dBm
Image rejection (88MHz)	>70dB
Transmit converter	
Power output (Saturated/P1dB)	+22/+20dBm
Transmit gain	20dB (35dB with optional TX IF stage)
Drive required for +20dBm output	0dBm (-15dBm with IF amplifier)
Harmonic output (2nd/3rd/higher)	-40dBc/-50dBc/<-60dBc
Image frequency output suppression	>70dBc
LO suppression	>70dBc

Table 1 Performance of the Anglian 3 144MHz transverter

Anglian 3 physical construction

Surface mount technology (SMT) is used for reproducibility. Moderately sized 0805 passive components have been used with corresponding semiconductor SMD parts.

The Anglian 3 PCB uses 1.6mm FR4 PCB material. The assembled PCB can either be seam soldered into a 60mmx 100mm tinplate box for screening and protection or mounted into an alternative screened box (aluminium cast, extruded or tinplate). Four holes are provided for mounting into an alternative housing. When used in the recommended tinplate box SMA (BNC and N types will not fit onto the small box) connectors are recommended for RF and IF inputs and outputs with solder-in feed-through capacitors for all power and control connections. The number of interfaces has deliberately been reduced from that available with the Anglian 1 and 2.



Anglian 3 circuit description

Mixer and local oscillator

Please refer to the schematic circuit diagram in Appendix 1 for the Anglian 3 component designations. A higher definition Schematic is included elsewhere on my web page.

An ADE1H level 17 (+17dBm local oscillator) mixer, MX1, is at the heart of the transverter. The mixer is used bilaterally, that is it is used both as the receive down conversion mixer and the transmit up conversion mixer. This arrangement economises on the use of expensive high level mixers and simplifies the LO (local oscillator) arrangement.

Although a level 17 mixer is used, it is fed with +20dBm of LO. This is within the specification of the mixer used and provides a useful increase in overall receive side dynamic range, whilst minimising conversion loss on both transmit and receive.

The reliable, low noise and very stable two stage Butler overtone crystal oscillator (XO), consisting of TR1 and TR2, operates at 116MHz.

144MHz - 28MHz = 116MHz

As the crystal oscillator in the basic Anglian 3 transverter is not temperature stabilised and oscillator stability is now crucial for most digital applications, provision is made to inject an external 116MHz local oscillator signal, if required. Alternatively a simple crystal heater can be used to increase the stability of the on-board oscillator by holding the crystal around 40°C.

Another method is to use injection locking. Injection locking provides a simple but effect way to retain the excellent LO phase noise performance of the on-board oscillator whilst using a less-than-perfect external 116MHz LO. This external LO can, in turn, be locked to the shack frequency standard for those critical frequency applications. The internal crystal oscillator could also be completely disabled and an external 116MHz LO used to replace it, if required. This might be done, for example, for diversity reception with two Anglian 3 receive converters.

In order to increase the LO drive from the 0dBm that the oscillator alone generates a PHEMT amplifier, IC5, is used to increase the 116MHz LO output to over +20dBm.

A single on-board +5V voltage regulator supplies both the LO and LO amplifier as well as the transmit and receive amplifier chains. Since the two amplifier chains draw similar current there is no large thermal shock between transmit and receive. A simple stick-on copper heat-sink helps remove excess heat from the voltage regulator. For best performance a 10-12v supply should be used, since the entire transverter works on 5V and excess voltage means extra dissipation in the voltage regulator. +10V is highly recommended, but I realise this voltage is not usually available in most shacks.

A low pass filter and diplexer is used between the LO amplifier output and the mixer LO input port. It might appear, at first sight, that the diplexer is connected the wrong way round, however its purpose is to absorb any unwanted products generated by the mixer and reflected back towards the LO amplifier. These products can reduce mixer performance and are best removed. A 0Ω resistor (bridge), R14, is provided between the diplexer and the mixer. By temporarily removing the link and substituting a short coax lead, the actual LO level can be measured. Simple voltage probe measurements at this point can be misleading due to the complex mixer LO port impedance. The diplexer values were carefully chosen to maximise performance and yet exhibit low loss to the 116MHz LO drive. A clean +20dBm is available to drive the mixer.

Transmit section

Separate IF (intermediate frequency) connections or ports are provided for the 28MHz transmit drive and receive converter output. If a single IF connection is required a hybrid coupler can be used to connect the two ports together whilst retaining a degree of isolation and limiting insertion loss to around 3.5dB.

As designed the Anglian 3 transverter can accept up to about 100mW of 28MHz transmit IF drive. This is deliberately less than with the Anglian 2. Dumping 2W of 28MHz energy, in the form of heat, into the transverter does not make sense. If you need to use more than 100mW then an external attenuator should be used!

The 28MHz (28 to 30MHz) transmit IF input is connected via the IF input connector to a variable L attenuator consisting of a 150Ω 0805 size resistor, R12; and a 500Ω variable resistor. Output, taken from the wiper of the surface mount variable resistor, is connected through a BAP64 PIN diode, D4, to the IF diplexer comprising C70, C19, L4, L7, L5 and R16 on the ADE1H IF port. This diplexer provides a good match to the mixer IF port whilst absorbing any unwanted mixer products. Control of the BAP64 diode is covered later in the section on transmit/receive switching.

If less than about -6dBm drive is all that is available then IC3 can be bridged into circuit to give around 18dB more gain, making the IF input suitable for use with some otherwise low transverter output level HF radios. As the 10m band transverter output spectrum of some of these radios may be a bit less 'clean' than expected, a single stage 29MHz bandpass filter comprising C6, C9, C13, C41, L25, follows the IF amplifier/non-amplifier to clean up the drive spectrum.

The mixer conversion loss measures slightly less than 7dB, resulting in a 144MHz output of approximately -10dBm. The following three pole band pass filter (BPF) has an insertion loss of about 2.5dB and a 1dB bandwidth of just over 4MHz. The 3dB bandwidth is about 6MHz. Note that no diplexer or other matching loss is inserted between the mixer and the BPF.

After switching in a second BAP64 PIN diode, D5, the wanted 144MHz transmit signal is amplified to around +8dBm in another PHEMT amplifier , IC7. The 88MHz image and 116MHz LO are suppressed well over 50dB at this point.

A two stage BPF in the transmit path further filters the output spectrum so that the image and LO frequencies and now suppressed well over 70dB with respect to the wanted output at 144MHz.

A second transmit PHEMT amplifier stage, IC2, is used to amplify the 144MHz filter output to over +20dBm at the RF output. The second transmit amplifier device has been changed to the same type of device as used in the receive post mixer stage. It has lower gain than the previously used SPF5043 and so is not so easily overdriven as in the Anglian2, with a subsequent improvement in stability and better IMD performance.

Increasing the 28MHz IF drive input to +3dBm results in the 144MHz output stage saturating at about +22dBm. The exact levels depend on how well the filters have been tuned. Use of the transmit IF amplifier will reduce the required IF power, to produce saturated output, to around -15dBm.

A low pass filter consisting of C62, C63 and L19, at the Anglian 3 transmitter output, reduces 144MHz harmonics to a low level prior to driving the following power amplifier.

Receive converter

This is identical to the circuit used in the Anglian 2. I didn't feel that it required any changes.

144MHz band signals enter the converter and pass through a noise matching circuit consisting of C45, C46, C47, C48 and L20 and then into an SPF5043 low noise, high dynamic range, PHEMT amplifier, IC6. This stage provides around 22dB of gain with a noise figure of 0.8dB (when added to the insertion loss of the noise matching filter). The SPF5043 has an output third order intercept (OIP3) of about +30dBm at 144MHz.

A BAP64 PIN diode , D6, switches the receive path to the following three stage BPF. This is the same BPF used in the transmit path. BAP64 PIN diodes were chosen because of their good IMD performance. They have been carefully biased for optimum performance.

After the BPF the ADE1H mixer frequency converts the signal down to 28MHz where the IF port diplexer ensures a good match to the mixer.

Another BAP64 PIN diode, D3, then switches the 28MHz receive IF to a very high dynamic range PHEMT post mixer amplifier, IC4. The MGA30689 has an OIP3 of +40dBm at 28MHz with a noise figure of less than 3dB. Its gain is flat from below 40MHz to over 3GHz at 14dB, with an excellent input match to 50Ω. It is a truly remarkable device.

A 29MHz bandpass filter consisting of C21, C22, C23, C24, C25, L1 and L2 suppresses any feed through of 116MHz local oscillator or other unwanted out-of-band signals from reaching the following 28MHz IF receiver.

Transmit/receive switching

Unlike the previous Anglian transverter P channel MOSFET high side switch devices are used to switch the +5V from regulator IC1 to either the receive converter or transmit converter amplifier chains and PIN diode switches.

In normal operation TR3 is off and this allows MOSFET TR4 to conduct with a very low on resistance. +5V is applied to the receiver chain. TR5 is held off via the positive voltage on C64 across the gate to ground. C64 will charge quickly, via diode D2, from switch on.

When the PTT line is grounded TR3 switches on in turn switching off MOSFET TR4 and the +5v supply to the receiver amplifier chain. C64 starts to discharge via high value resistor R32. After about 150ms (depends on the value of 64 fitted) TR5 is able to switch on and supply 5V to the transmit amplifier chain. The length of this transmit enable delay can be adjusted by changing the value of C64 and/or R32. C64 is shown as 1uF, but 0.1uF will give a shorter transmit enable delay.

When the PTT ground is removed C64 quickly charges through diode D2, switching off TR5 and removing the +5v supply from the transmitter chain, whilst TR4 switches on and supplies 5V to the receiver chain.

For assurance green LEDs on the board indicate transmit and receive states. The over-coax switching used in the Anglian2 is no longer provided.

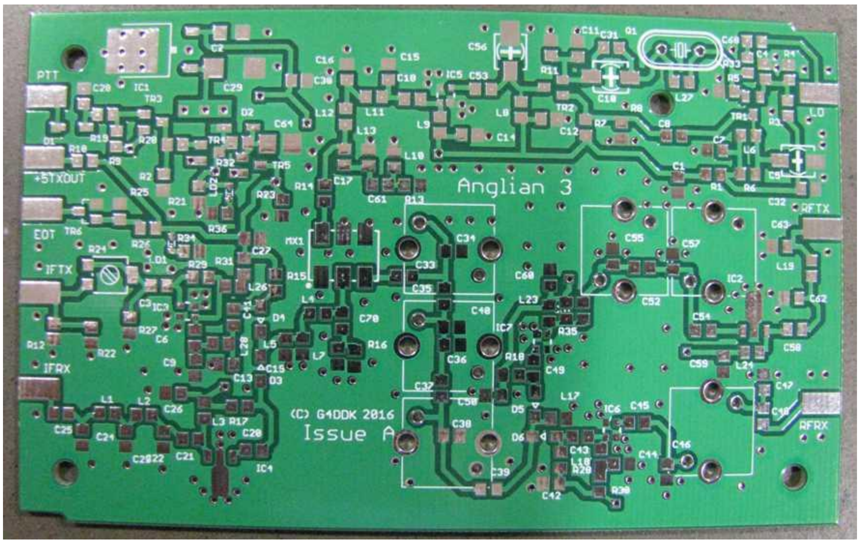
TR6 is a low power N channel MOSFET switch that is turned on when the Anglian is switched to transmit. Resistors R25 and R26 ensure that TR6 is held off until the voltage from TR4 rises high enough to switch on. TR6 drain output provides a convenient ground connection to enable (turn on) an external linear amplifier requiring earth on transmit (EOT).

5VTX_OUT is provided as fixed bias to enable the RA08H1317M 8W power amplifier module on transmit (described separately.)

The EOT output can also be used to switch an external relay to +12V, if required. The current sunk here should be limited to about 100mA.

Construction of the Anglian transverter

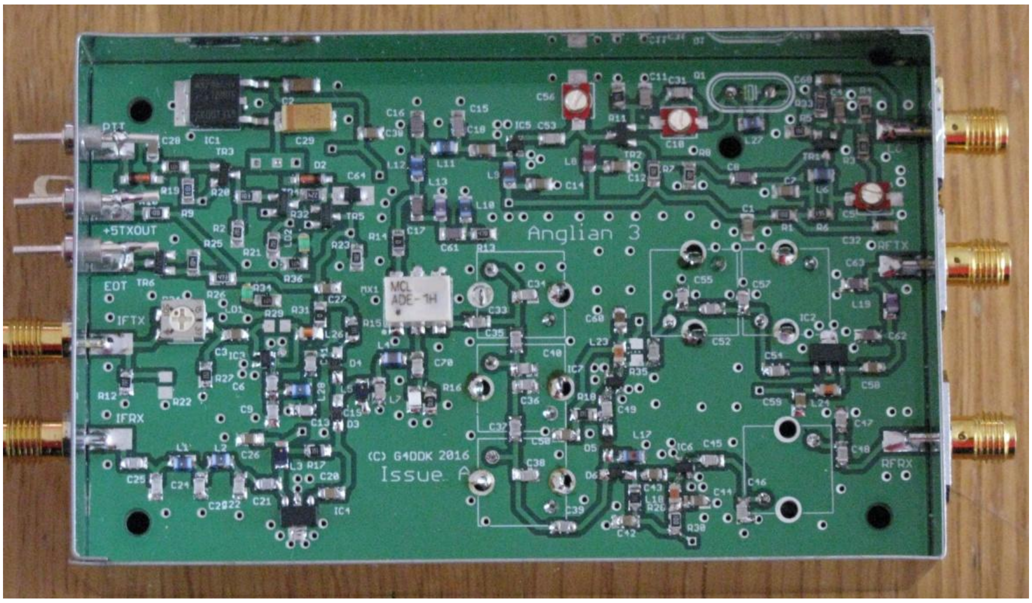
A double sided FR4 PCB of 60mm x 100mm is used to accommodate the transverter. It is highly recommended that the transverter is seam soldered into the recommended tin plate box to provide screening and protection for the small SMD parts used in its construction. Four M3 mounting holes are, however, provided in the PCB to enable the PCB to be mounted onto a base-plate if the tin plate box is not required.



The external LO connection and the 144MHz transmit and receive connections are located at one end of the board and the 28MHz IF connections at the other end. All of the DC input and output connections are also located at the IF end of the PCB. Tusonix 1000pF feed-through capacitors are recommended to decouple all of the DC connections into and out of the screened box.
All SMD parts are on one side of the PCB whilst the HC43/U 116MHz crystal (Q1), and tuneable Coilcraft coils L14, L15, L16, L20, L21 and L22 are located on the other side of the PCB, together with the series diode 1N5401 used to drop the supply volts and provide reverse polarity protection.

Some constructors may prefer to mount the completed Anglian 3 transverter board (module) in an alternative housing, such as one of the small 1/2 Eurocard size (100mm x 160mm) Hammond boxes. Mounting holes enable this to be done, but note that access to the underside of the board will be difficult unless access holes for the transmit power attenuator R24 and the trimmer C10 are

provided in the base of the housing. Thin coaxial cable can be used to connect to suitable RF coaxial connectors on the rear of the case.
Due to the extensive use of plated through holes both for RF ground integrity and heat transfer the use of home produced PCBs are not recommended. Low cost, commercially made, PCBs are available from the author. The Anglian transverter can also be supplied as a complete kit of parts. No PCB Gerbers or masks are being made available.



Due to the use of SMD components (lots of them) the Anglian 3 transverter project is only recommended for those with experience of larger SMD projects. It is definitely not a beginners SMD project.

The economics of small assembled RF board runs are doubtful. This situation may change later, but initially supply will be limited to kits and boards.

Once the SMD board is assembled you will need to either solder the board into the tin plate box and then fit the connectors and feed-through capacitors; the six tuneable coils and the crystal, onto the board. If the board is to be bolted into a case then these parts can be mounted now.

A separate, full, Assembly Manual is provided for those wishing to build the Anglian 3 transverter.

Alignment and system connections are dealt with in the Operators Manual. This will be available on my web page.

Acknowledgements
G4SWX - Filter improvements and general advice on measurements

G7OCD - Original PCB advice and library components Document history

Issue	Date	Comments
V0 .4	9/9/2016	Draft
V1.0	12/9/2016	Reviewed
V1.1	27/9/2016	New Schematic
V1.2	5/11/2016	Updated Schematic

Appendix 1 Anglian 3 Circuit schematic diagram