MULTI PURPOSE TRANSVERTER MODULE

A C Talbot G4JNT Dec 1994

SYSTEM DESCRIPTION

The transverter module described is designed primarily for 144 to 1296 MHz but may be adapted for other conversions such as 28 to 432 MHz and 28 to 1296 MHz or, (non ideally) 432 to 1296 MHz and 144 to 432 MHz

The unit includes four subsections.

· A local oscillator chain.
Suitable for generating frequencies up to around 1300 MHz. The circuit is based on the DDK001 design, adapted for surface mount.

· The RF section.
A double balanced mixer operates bi-directionally for transmit and receive frequency conversion; this is followed by a two section helical filter for image and LO rejection. Broadband transmit and receive amplifiers complete the RF chain, giving a transmit power output of between 0 and 6 dBm, depending on frequency, with a typical receive noise figure of 4dB. Tx/Rx switching is performed by solid state switches. Separate RF ports for Rx and Tx are provided. By addition of a transmit amplifier chain, a low noise amplifier and antenna changeover relay, a complete transverter system can be built. However, for high power work, additional RF filtering of the transmitted signal is required.

Both mixer and helical filter are drop in units. The helical filter is available for a number of frequency ranges between 400 - 1300 MHz.

· A T/R switched power attenuator. PIN diode switched power attenuator rated up to 3 watts and IF preamplifier for receive.

· Tx/Rx DC voltage switching. An interface unit for low power tranceivers such as the IC202 and FT290. The DC level on the antenna feed of the transceiver is used to control switched 12V DC supplies for use within the module. These supplies are available on connectors to externally control separate equipment and are rated at up to 250mA.

The tranceiver interface is electrically the same as the JNT001 unit, with additional components for the common Tx/Rx mixer and receive preamplifier.

A block diagram of the module is given in figure 1 with the gain and power distribution budget, it should be noted that the gain distribution is based on worst case figures with the MSA series MODAMPS. It is quite likely that considerably more gain and power output will be available in practice. The complete circuit diagram is shown in figure 2. Details are given for the 144 to 1296 MHz version.

COMPONENT AVAILABILITY

All surface mounted and other components are available from Farnell except for the following:

DC2850E BFR53 and TUF-2 (Avaiable from the Microwave Components Service)

MSA series Modamps (Cirkit, Bonex, Mainline etc.)

Helical Filter (Cirkit)

CONSTRUCTION

With a few exceptions, components are surface mount types fitted on a single substrate. Exceptions are the trimmer capacitors in the LO chain, the mixer and helical filter which are designed for through hole mounting. The 55mm x 145mm PCB is fitted in a standard tinplate box type 7768.

Figure 3 shows the component layout from the underside of the board.

Start by inserting all the grounding and interconnection through pins. Refer to Figure 4 for the positions of these. Solder the grounding pins on both sides of the board and crop off excess length. Do not insert pins in the places marked with a hollow circle as these are for component leads to pass through.

Next fit the RF connectors and feedthrough capacitors for DC feeds to the tinplate box. Mark the positions of the three RF ports on the end wall, and drill 3mm diameter holes at a height of 12mm from the bottom or track side of the box. Solder the connectors then place the PCB against the protruding centre pins. Mount the PCB into the box by seam soldering all around the ground plane on the top side. It may be necessary to trim the board to size. Then also seam solder on the component side at all places where the lower ground plane approaches the edge of the board. This step is important as a lot of the RF grounding is via this path.

It is best to separately build and test each of the four circuit subsections in the order given.

Oscillator stage

Start with the LO chain as this does not require any of the switching circuitry to be operational.
Mount all the SMT components and the voltage regulator. Inductors L12 - L13 are fitted surface mount style on the underside by bending their connection leads horizontal. The two inductors should nearly touch to achieve suficient coupling. The oscillator inductor L11 is shown fitted to the underside of the board; if it is considered necessary to have this on the top side to simplify access to all

tuning controls, counterbored holes will need to be drilled. It is helpful if L11 is mounted as far to the left as possible in order to make room for other components. TR6/7 are fitted by bending their legs down and then horizontal as shown in Figure 5. The emitter decoupling capacitors, C30 and C38 should be mounted as close to the transistor as possible. The trimmer capacitors are fitted on the top or groundplane side, with the ground connection made by bending the flat lead of the trimmer horizontal and soldering to the groundplane.

Do not solder in the mixer yet. The crystal lies flat, but above the component level, on the underside of the PCB. It may be secured by soldering the top of the can to a PCB pin or piece of wire inserted through the adjacent hole and connected to ground.

Apply 12V to the LO supply pin (+12V) and ensure 8.2V is available at the output of the voltage regulator, IC6.
Using a VHF broadcast receiver or scanner (!!) tuned to 96 MHz, adjust L11 until the circuit is oscillating. Then monitor the voltage on TR6 emitter and adjust C27 and C28 for a maximum reading. This should peak at around 0.5V. If it is not possible to resonate these tuned circuits, additional fixed capacitors of 1 or 2 pF may be connected in parallel with the trimmers on the track side of the board. Alternatively 10 pF units may be substituted although tuning will then be very sharp.
Transfer the voltmeter to TR7 emitter and peak C35/C36 for a maximum of around 0.6V. Finally, peak C40/41/42 for maximum 1152 MHz output at the point where the LO injection to the mixer occurs; ie at the end of the track from the tap on L18. (This is why the mixer was not soldered in yet!). The circuit of a simple power meter is given in Appendix A.

Using the power meter described, a reading of between 0.8 to 1 Volt, should be easily obtained providing the correct emitter voltage has been achieved in the previous stages. This power meter reading corresponds to a local oscillator injection of between 9 and 11 dBm. If LO injection is significantly above this level, it may be reduced by increasing the value of R44. If a frequency meter is available adjust L11 for a frequency of 1152 MHz measured at the mixer. Depending on the crystal, it may prove necessary to alter the value of Cx to obtain reliable oscillation at the wanted frequency. This completes the LO tuning up.

DC Control Circuitry

This part is constructed next as switched supplies are required to test the remaining sections of the transverter. R7 and R8 are mounted off-board, between the PCB pins and their respective feedthroughs. The black band on the chip tantalums is the positive end. Apply +12V to the input supply pin and ensure that 12V is generated at the select polarity pin (A). Apply greater than 3V to the transceiver DC input pin (X) and ensure the 12V supply swaps to the other polarity select pin (B). Ensure 250mA can be drawn from each switched rail with a voltage drop of no more than 1V.

If DC control from the transceiver antenna connection is to be used check and note carefully which of these pins A and B are transmit and which receive. For the IC202 pin A is transmit (+12 Tx) and for the FT290 pin A is receive (+12 Rx)

Transceiver RF switching

Fit all components for this part of the circuitry, up to and including C9 on the mixer feed, leaving the PIN diodes until last. Do not fit IC5 yet. To avoid breaking the PIN diodes, carefully bend the leads down at a distance of 1mm from the glass body by using a pair of thin pliers or tweezers to hold the wire away from the glass. The IF drive preset, R19, may be mounted on the top of the board if desired.

Connect the links on the top side of the PCB as shown in figure 6 to the selected A and B pins. Connect the transceiver and ensure the supplies still toggle correctly between transmit and receive.

Using the diode power meter described above, it should just be possible to detect RF at the output of the IF drive preset resistor (R19) when driving with 1 Watt of RF, the voltage detected should be no more than 0.4V, and may not even be seen if using a 1N914 type diode. Any higher reading than this indicates an error either in DC switching or power attenuator grounding.

When these tests are satisfactory, insert IC5 and ensure the received noise level rises appreciably when power is applied to the receive chain. This completes the transceiver interface. Leave R19 set to maximum output, or 0dBm, whichever is lower.

1296 MHz section.

This is probably the simplest part of the circuitry to set up. Fit all components from the mixer onwards. The orientation of the mixer is such that the ground pin, connected to the case, passes through the hole where the groundplane is not relieved. The modamps are fitted by bending their input and output leads as for the oscillator/multiplier transistors, then bending the two grounding leads downward, passing them through the relevant holes and soldering on <u>both</u> sides of the board.

Inductors L6 to L10 consist of 7 turns of 0.25mm wire on a 2mm diameter former spaced 1mm above the board on the component side. The use of self fluxing enamelled wire will make the assemply of these components easier. Mount the rest of the components, not forgetting the 100nF supply decoupling capacitors C45 and C46. These are necessary to prevent LF instability (around 20 MHz) caused by a feedback network generated by the bias chokes and 220pF decoupling capacitors. The grounding tabs on the ends of the helical filter are bent horizontal and connected to the ground plane. The centre grounding tab is soldered on the underside.

Eventually the mixer and filter should have their cases fully soldered to the ground plane on all four sides to optimise their isolation performance. However, this rather drastic move need only be made after the transverter is satisfactorily RF tested, and requires a moderately powerful soldering iron if a good quick joint is to be made.

Apply transmit power to the IF port and ensure that RF at the appropriate output frequency is produced. To measure the output it will be necessary to find some means of indication of RF power around the 0dBm level. It is unlikely that the simple power meter described above will be suitable unless a good quality schotty diode is used. An alternative would be a well screened receiver or converter for 1296 MHz with a good quality load on its antenna terminal.

Minor adjustments may be made to the helical resonator filters to maximise output power, but no more than one turn to each of the adjusting screws should be required; the two screws are interactive to a slight degree. Reduce the mixer drive level with R19 and check that the power decreases smoothly to zero. If a sensitive power meter or spectrum analyser is available, it may be possible to detect other spurious outputs. These should be at a level of at least 30 dBc, and typically 40 dBc.

On receive, the noise level should be significantly higher than that due to the IF amplifier alone and it may be possible to hear the noise level change when the input is terminated. If it is intended to use an extra low noise amplifier on receive, it is probably advisable to leave out one of the receive amplifier modamps to prevent too much gain and consequent overloading on strong signals. In this case bridge the signal tracks with a piece of copper tape, leaving out the bias components L10 and R28.

During ß testing, several chip capacitors cracked, presumably due to rough handling, so if any unpredictable or intermittant effects are seen look carefully with a magifying glass for any cracked capacitors. The ones around L12 and L13 seem to be particularly vulnerable.

SCREENING AND SPURIOUS OUTPUTS

If the module is not going to be used where additional filtering is provided for spurious products (eg. waveguide filters in SHF/EHF transverter systems) or with a PA stage for a transverter system, then a closed screen is needed over the RF circuitry on the under side. This is made from a piece of tin plate or brass sheet, L-shaped and measuring 30 x 40 x 12mm, just not touching the lid of the box. It is soldered at 5 roughly equally spaced points to the inside groundplane track, and to the sidewalls of the box. A lid of 30 x 40mm is soldered to the top of this added wall. To facilitate later removal the lid need only be spot soldered in two places.

With the screen in place and both lids fitted, measured spurii on one ß test model are as tabulated below:

1152 MHz	Local oscillator	–37 dBm
1108 MHz	Image response	–35 dBm
1296 MHz	Wanted output	+5.8 dBm
576 MHz	½ LO	–30 dBm

In some cases a ninth harmonic component of the 144 MHz drive signal has been observed on the transmit output which does not vary as R19 is adjusted. This is generated in the PIN diode switch if too high a level of 144 MHz is applied to the input of the transverter. The circuit should be satisfactory up to drive levels of 3W and certainly will be so at the 1W level. Drive levels above 3W should be avoided anyway as the dissipation ratings of the attenuator resistors will be exceeded. If an IC202 is used as the driver, it is relatively straightforward to reduce the output to 1W by adjustment of the transmitter ALC preset.

MODIFICATIONS FOR OTHER FREQUENCY RANGES

The IF stages are broadband and will operate over the range 10 MHz to 432 MHz. The frequency ranges over which the transverter can be made to operate are determined only by the helical filter; all amplification is broadband. The filters are available as drop in units covering the frequency range 350 - 1340 MHz and also 1540 MHz. The specified mixer will operate with adequate performance to 1300 MHz and a higher specification unit, the TUF-5, can be used as a replacement for frequencies above this.

The area needing modification for different frequencies is the local oscillator chain. With modifications to L11 and possibly C23 to oscillate at the correct frequency, the existing LO chain will cover the range approximately 800 MHz to 1400 MHz.

For frequencies lower than this two solutions are possible. By replacing C40-C42 by higher value trimmers, the output stage can be operated as an amplifier rather than a doubler. However, if this route is chosen the value of R44 needs to be increased to prevent overdriving the mixer with LO signal.

The other alternative is to leave out TR7 and associated components and take the LO drive from the tap on L15 using a piece of thin coaxial cable to bridge the gap. The track from L18 will need to be cut. For frequencies around 300 MHz, (eg 144 to 432 conversion) TR6 will operate as an amplifier and the values of C31/C32 will need to be increased; the value of R40 being altered to optimise drive level.

For use at lower RF frequencies, eg 144 MHz, it may be possible to replace the helical filter with two coupled tuned circuits on the top side of the PCB. There is space for this if air wound coils are used with trimmer capacitors. Note that the output side of the filter is not connected directly to ground, but via a 560Ω resistor for biassing the switching diodes.

COMPONENT LIST

Quantity	Reference	Part
1	TR1	BC846
2	TR2,TR3	IRFR9024
2	TR4,TR5	BFR53
1	TR6	BFR91A
1	TR7	BFR96A
3	IC1,IC3,IC5	MSA0104 or MAR-1
1	IC2	MSA0304 or MAR-3
1	IC4	MSA0686 or MAR-6
1	IC6	78L082
4	D1,D2,D3,D4	DC2850E
2	D6,D5	1N914 or 1N916
6	R1,R2,R3,R4,R5,R6	5k6 1206 SMT
5	R9,R21,R30,R35,R36	1k
1	R17	39
1	R18	100
4	R20,R26,R28,R29	270
2	R22,R24	330
2	R46,R47	18
2	R25,R34	560
1	R27	150
1	R31	820
1	R32	470
1	R37	390
2	R38,R42	22k
2	R39,R43	2k2
2	R23,R40	22
2	R41,R45	12
1	R44	27
2	R7,R8	2.2 1W Wire ended
2	R10,R11	330 0.5W "
2	R12,R12A	15 " "
1	R13	180 " "
2	R14,R15	150 " "
1	R16	120 " "
1	R19	100 Preset
15	C1,C2,C3,C4,C5,C6,C7, C8,C9,C21,C22,C26,C29 C43,C44,C47,C48	1n 0805 SMT
6	C11,C10,C12,C13,C17,C18	100p "
9	C14,C15,C16,C19,C20,C31, C32,C38,C39	220p "
1	C23	10p "
2	C24,C25	22p "
1	C30	470p
1	C33	220n 1206 SMT
1	C34	1u "
2	C45,C46	100n "
2	C27,C28	10pF Trimmer 5mm Dia
5	C35,C36,C40,C41,C42	6pF Trimmer "

4	L2,L3,L4,L5	220nH 1812 SMT
1	L11	Toko MC119 200nH, Cirkit Stock No. 35-11954
1	Helical Filter	Cirkit Type 5HW 2 Pole 367MN-113F (for 1296 MHz)
1	Mixer	Mini-Circuits TUF-2

Inductor Winding Details

L12, L13 3 turns 0.5mm φ enamelled copper, 3.2mm inside φ, spaced to fit board. Height 1.5mm above board.

L6,7,8,9,107 turns 0.2mm φ enamelled copper, 2.5mm φ close wound.