The “Duet” Dual-Band CW Transceiver

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Figure 1 – The "Duet" Dual-Band CW Transceiver

Introduction

The "Duet" was designed as an entry for the South African Amateur Radio Development Trust's 2005 construction competition. The competition called for "a low power two-band HF CW transceiver for 20 and 40 metres, fully tunable with an output of at least 10 watt. The design must use locally available components and in kit form must not cost more than R500 excluding the cabinet." [1]

The approach I chose uses a blend of old and modern techniques: a direct-conversion receiver with a direct digital synthesis (DDS) local oscillator and microprocessor control. The direct-conversion architecture minimizes the cost, and since it does not use an IF filter, avoids the need for an expensive monolithic filter or matched crystals. The DDS local oscillator gives a wide tuning range with crystal-controlled stability, and does not require the mixer or multiplier stages that would be needed for a traditional VFO-based design to cover two bands. The microprocessor, as well as controlling the DDS, makes it easy to provide a comprehensive feature set including digital frequency read-out and a built-in CW keyer.

One of my objectives was to make the design as easy to reproduce as possible, so I used printed-circuit board construction and adopted a "zero-alignment" approach: there isn't a single adjustment except for the front-panel controls, so no test equipment is required to get it working. I also tried to make the design as foolproof as possible by including reverse-polarity protection and a robust MOSFET power amplifier that can withstand badly mismatched loads without damage.

[1] www.amateurradio.org.za/Construction.htm

The “Duet” is intended primarily as a base station for school and community stations, rather than for portable operations. For this reason the emphasis is on delivering as much usability and functionality as possible, rather than minimizing the size, weight or power consumption.

Circuit Description

The “Duet” consists of two PC boards: the signal board, which contains the DDS local oscillator and all the RF and AF circuitry; and the control board, which contains the microcontroller, seven-segment LED displays and push button switches. The circuit diagram of the signal board is shown in Figure 2.

Low-pass Filters

The antenna is connected via DC blocking capacitor C1. R1 provides a ground path for the small DC current that flows through the relay contacts during receive to ensure that they have low impedance at signal frequencies. Relay K1 selects which of the low-pass filters is used. L1-L3, C2 and C3 are the 20m low-pass filter, a Chebyshev design with 0.9 dB ripple, a cutoff frequency of 16.0 MHz and 37.8 dB rejection of the second harmonic at 28.0 MHz. L4-L6, C4 and C5 are the 40m low-pass filter, a 5^{th} order Chebyshev with 0.6 dB pass-band ripple and a cutoff frequency of 8.5 MHz. Rejection is 30.6 dB at 14 MHz. The cutoff frequencies are higher than the upper limits of the bands to allow for component tolerances.

Transmit/Receive Switch

The receive signal path is through the transmit/receive switch consisting of diodes D1 and D2 which prevents the transmitter output from damaging the receiver front-end, To minimize cost standard signal diodes are used in place of PIN diodes. During receive, the ~MUTE line is open circuit, so no current flows through RF choke L7. R2 holds the anodes of the diodes positive, while the cathodes are grounded through R1 and R3, allowing both diodes to conduct. During transmit the ~MUTE line is held low, so no current flows through the diodes and they are shut off.

C6, C7 and L8 form a high-pass filter that rejects the strong signals found in the AM broadcast band that would otherwise overload the mixer. It is a 3^{rd} order 0.5 dB ripple Chebyshev with a cutoff frequency of 6.0 MHz and 49.6 dB rejection at 1.0 MHz. The design uses separate low-pass and high-pass filters both for simplicity and to allow a “no-tune” design, as the low- and high-pass filters can be designed with sufficient headroom that they will function correctly even if component variations move the cutoff frequency by 10% or so. Another advantage is that no high-Q sections are required, so standard value off-the-shelf RF chokes can be used for the inductors.

RF Amplifier

Q1 and associated components form the RF amplifier. A BF199 was selected for its good noise figure of 2.5 dB with a 50Ω source impedance. The collector current is 10 mA to give good intermodulation distortion (IMD) performance. R7 provides a small amount of emitter degeneration to reduce gain and improve linearity, although its value is a compromise as its noise voltage is effectively added to the input signal, so the value of R7 must be small compared to the source impedance in order to prevent too much degradation of the overall noise figure. R8 provides additional emitter degeneration at DC to allow stable biasing. R5

provides shunt feedback to reduce the input impedance to 50Ω. The stage has a voltage gain of about 20.

Mixer

The mixer uses an inexpensive CMOS analog multiplexer, the 74HC4053 (IC2), which consists of three independent 2-1 analog multiplexers. The three multiplexers are connected in parallel, to reduce the "on" resistance and used to route the RF signal from the collector of Q1 to either C9 or C10, depending on the polarity of the local oscillator signal. So for half of each cycle of the local oscillator the RF signal is connected to C9, and for the other half of each cycle it is connected to C10. This provides a mixing action, with the RF signal being effectively multiplied by the square wave local oscillator. C9 and C10 act as low-pass filters, and the voltage developed across C9 is used as the output of the mixer. The "inhibit" pin of IC2 is pulled high during transmit, stopping the mixer and muting the receiver.

Audio Preamp

Q2 serves as a low-noise audio preamp, operating with a collector current of 280uA and a source impedance of 1 KΩ (twice the output impedance of the RF preamp). It has a voltage gain of over 100 at 500Hz, while at lower frequencies the increased impedance of C11 reduces gain to minimize mains hum.

Variable-Gain Amplifier

R11-R14 provides bias voltages to the variable-gain amplifier (VGA) and AGC detector. The objective is to provide a voltage of approximately half the supply voltage to bias the VGA, and a slightly higher voltage (by about 400 mV) to set the AGC threshold. The voltage drop across R13 provides the difference between the bias voltages, while R11 and C13 decouple the bias voltage from the signal line.

The VGA consists of two identical stages around IC3B and IC3A. The high-frequency response is rolled off by the input filter capacitors C14 and C18 to improve the overall selectivity. The low-frequency response is rolled off by C16 and C19, to reduce hum and allow easy biasing since the gain is unity at DC. The P-channel JFETs Q3 and Q4 are operated in the linear region with no bias current and serve as variable resistors (they are drawn correctly, with their sources earthed, even though in normal applications the source of a P-channel JFET is usually more positive than the drain). As the AGC voltage at their gates is increased, the FETs pinch off, increasing their drain-source resistance and reducing the gain of the VGA. Resistors R16, R17, R20 and R21 apply half of the drain voltage of the FET to its input, to linearize their "variable resistor" operation[2]. The total gain of the VGA can be varied from unity to approximately 80 dB.

AGC Detector, Integrator and Filter

IC3D is the AGC detector. It operates as a comparator, swinging its output low when the input signal (applied to the negative input of the op-amp) exceeds the threshold set by R13. When this happens, D3 conducts, ramping up the voltage at the output of the integrator IC3C, which is filtered by R25 and C26 to provide the AGC voltage. R23 sets the AGC attack time, while R24 sets the decay time. When the receiver is muted, Q5 is turned on, forcing the AGC line high and reducing the gain of the variable-gain amplifier to the minimum.

[2] Horowitz, P. and Hill, W., 1980, *The Art of Electronics*, 2nd Edition, p. 139. Cambridge University Press, Cambridge.

Audio Power Amplifier

IC4 is the AF power amp. It has a gain of 20 and a maximum output power of 250 mW, which is quite sufficient to drive headphones. The AF gain control, a 10k potentiometer with a logarithmic taper, is connected to SV1.

Power Supply

The 13.8V DC power supply for the transceiver is connected via D5, a Schottky rectifier with a forward voltage drop of only 525 mV at 3A which provides reverse polarity protection, and fuse F1. IC1 provides a regulated 9V supply for the RF preamp, audio preamp and variable-gain amplifier. This improves the rejection of mains hum and prevents the AGC system from being affected by the supply rail fluctuations that occur when the transceiver transmits. IC5 provides a regulated 5V supply for the DDS and CMOS mixer.

Local Oscillator

The local oscillator consists of IC6, an Analog Devices direct digital synthesis (DDS) chip, and associated components. The clock signal and frequency reference for the DDS comes from OSC1, a 50 MHz crystal oscillator module with a frequency stability of 50 parts per million over a temperature range of 0 - 70ºC. The DDS output frequency is programmed by the microcontroller (IC7, on the control board) via a three-wire serial bus (the pins labeled SDATA, SCLK and FSYNK on IC6). The DDS output, a sampled sine wave, appears at pin IOUT of IC6. The output is a current source that develops a voltage across R40. C39-40 and L9 form a low-pass filter that suppresses the alias frequencies that appear in the output of the DDS. It is a Chebyshev filter with a cutoff frequency of 16.5 MHz and 0.8 dB pass-band ripple, designed for a source resistance of 200Ω and a load of 100K. The filter provides 24.5 dB rejection at 35.9 MHz, the lowest alias frequency. The signal is fed to the on-board comparator via the VIN pin, which converts it to a CMOS-level square-wave at the SBOUT pin, which is fed to the receive mixer IC2 and the RF power amplifier.

Buffer, RF Driver and Power Amplifier

Q10 is an emitter-follower that buffers the local oscillator signal. Q9 amplifies the signal, from about 3V peak-to-peak to the 6V peak-to-peak or so required by the MOSFET output stage (Q6). R64 limits the base drive to Q9 to avoid charge storage problems, while C50 allows an initial strong current pulse to turn the transistor on or off. Q7 and Q8 form a push-pull emitter-follower driver stage that provides the high current drive required to overcome the gate capacitance of Q6. D6 partially compensates for the base-emitter voltage drops of Q7 and Q8 and also prevents the bias voltage present at the base of Q9 from reaching the gate of the MOSFET via R30 and R28. TR1 reduces the 50Ω antenna impedance to 12.5Ω, which allows the MOSFET to generate 5-10W out.

The collector voltage for Q9 is provided by Q11, an emitter-follower that buffers the voltage across C31. When the ~KEY line goes low, Q12 turns on and charges C31 through R35. The gradually rising voltage (rise time about 5 mS) generates a properly shaped CW keying waveform to minimize key clicks. When the ~KEY line goes to a high-impedance state, C31 discharges through R35 and R36, shaping the trailing edge of the keying waveform. The output of Q11 is also applied to the gate of Q6 through the voltage divider consisting of R28 and R29. This biases the MOSFET almost into conduction when transmitting. Q14 operates as a switch, incorporating R65 into the bias network when the 40m band is selected to adjust the bias level to suit the different drive levels available on 20 and 40 metres. When not transmitting, the MOSFET gate is held low by R29, shutting the device off.

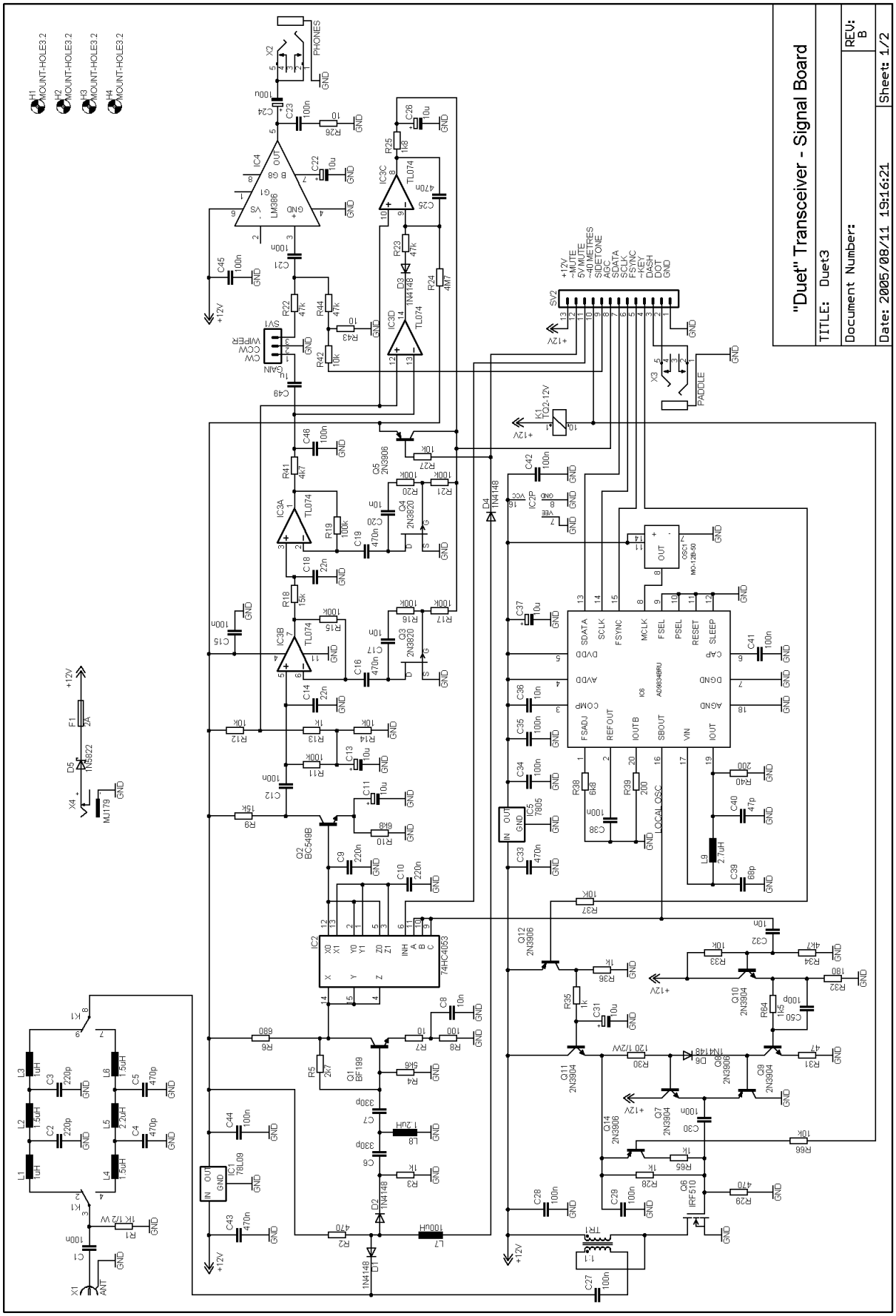

Figure 2 – Schematic of the Signal Board

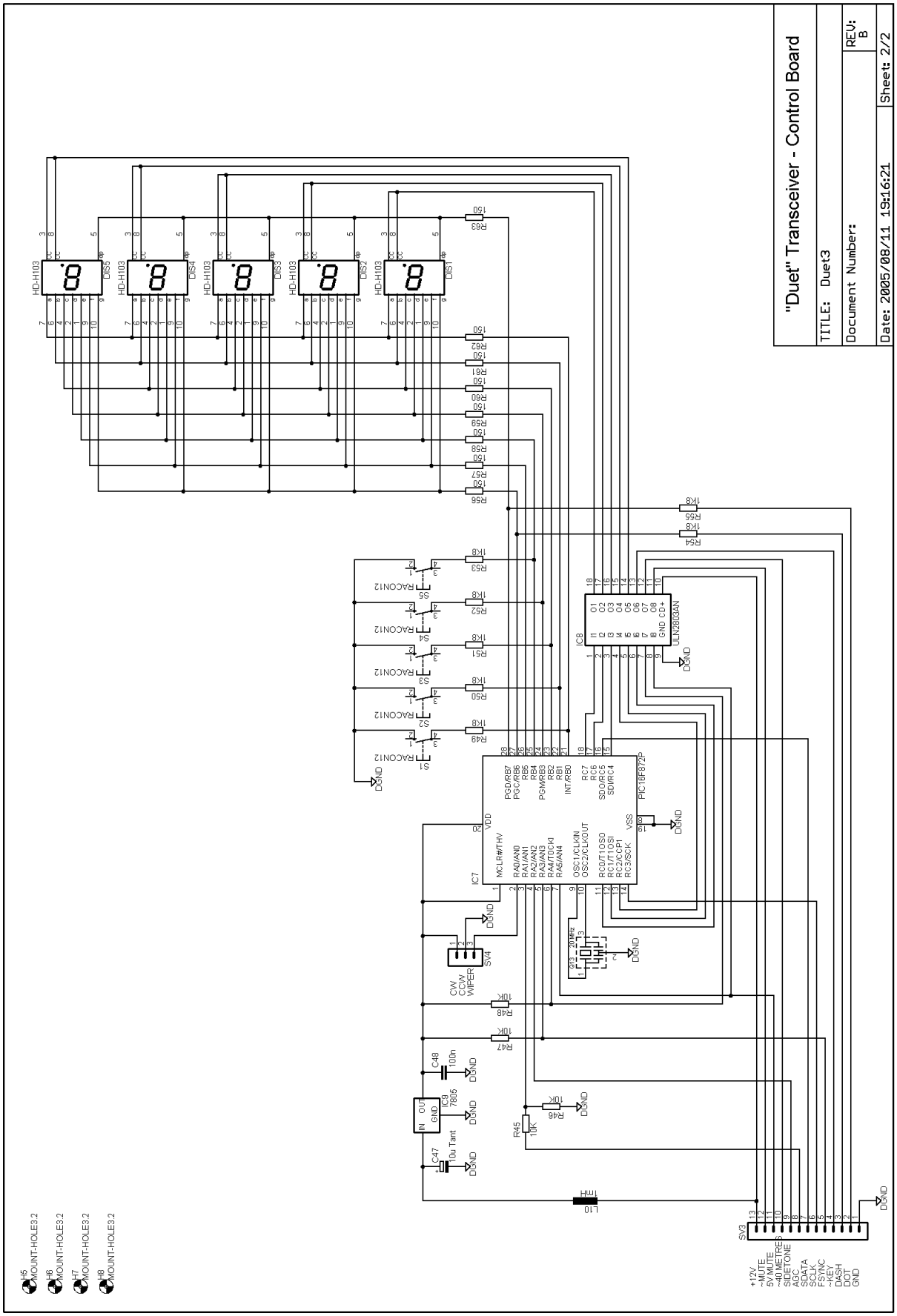

Figure 3 – Schematic of the Control Board

Control Board

The circuit of the control board is shown in Figure 3. IC7 is a PIC microcontroller that controls the transceiver, operates the display and provides auxiliary functions like the integrated CW keyer. The five 7-segment displays, DIS1-DIS5 are multiplexed, so only one of the digits is illuminated at a time, but the microcontroller sequences rapidly through the digits to give the impression that they are all illuminated simultaneously. The anodes of the displays are controlled by I/O port B of the microcontroller, which also doubles to read the control buttons S1-S5 and paddles. The cathodes of the display are controlled through IC8, and eight-channel Darlington driver array that provides the high current-sinking capacity required (up to 160mA when all display segments are illuminated). IC8 is also used to buffer signals that will control 12V circuitry on the signal board.

The tuning control, a 10k linear potentiometer connected to SV4, is connected to an analog-to-digital converter (AN0) on the microcontroller. The AGC line is fed to another analog-to-digital converter (AN1) via the voltage divider consisting of R45 and R46 so the AGC voltage can be used to display an S-meter reading.

IC9 provides a regulated 5V supply for the microcontroller, and C47 and L10 form a low-pass filter to prevent RF hash generated on the control board from being fed to the signal board via the 12V supply line.

Construction

Note that many of the semiconductors used in the "Duet" are static sensitive. Ideally, you should earth yourself using a resistive earth strap; use an earthed soldering iron and work on an earthed conductive mat when handling these components or a board that contains them. If you don't have access to this equipment, then at least ensure that you earth yourself and your soldering iron before and at regular intervals while handling them.

In order to keep the cost of producing the printed-circuit boards as low as possible, the signal board and control board are fabricated together as a single 164mm x 87mm PCB. The division between the boards is clearly marked by a dotted line silk-screened onto the board and by the mounting holes that mark the corners of each of the boards. Use a hacksaw to cut the PCB into the two boards, being careful not to cut any tracks on the board. After cutting the PCB, lightly sand the cut edges with 400 grit paper and wipe the boards with a tissue to remove the dust.

Please refer to the parts placement diagrams (figures 3 and 4) to ensure that you place parts in the correct position and orientation.

Control Board

Start by assembling the control board. Note that the seven-segment displays, DIS1-DIS5, and the control switches, S1-S5, are mounted on the *bottom* of the board. The bottom is the side that does not have a silk-screened legend. All the other components are mounted on the top of the board. I suggest installing the components that are mounted on the top of the board first; as if the displays and push buttons are installed first they will obstruct access to the leads of some of the other components.

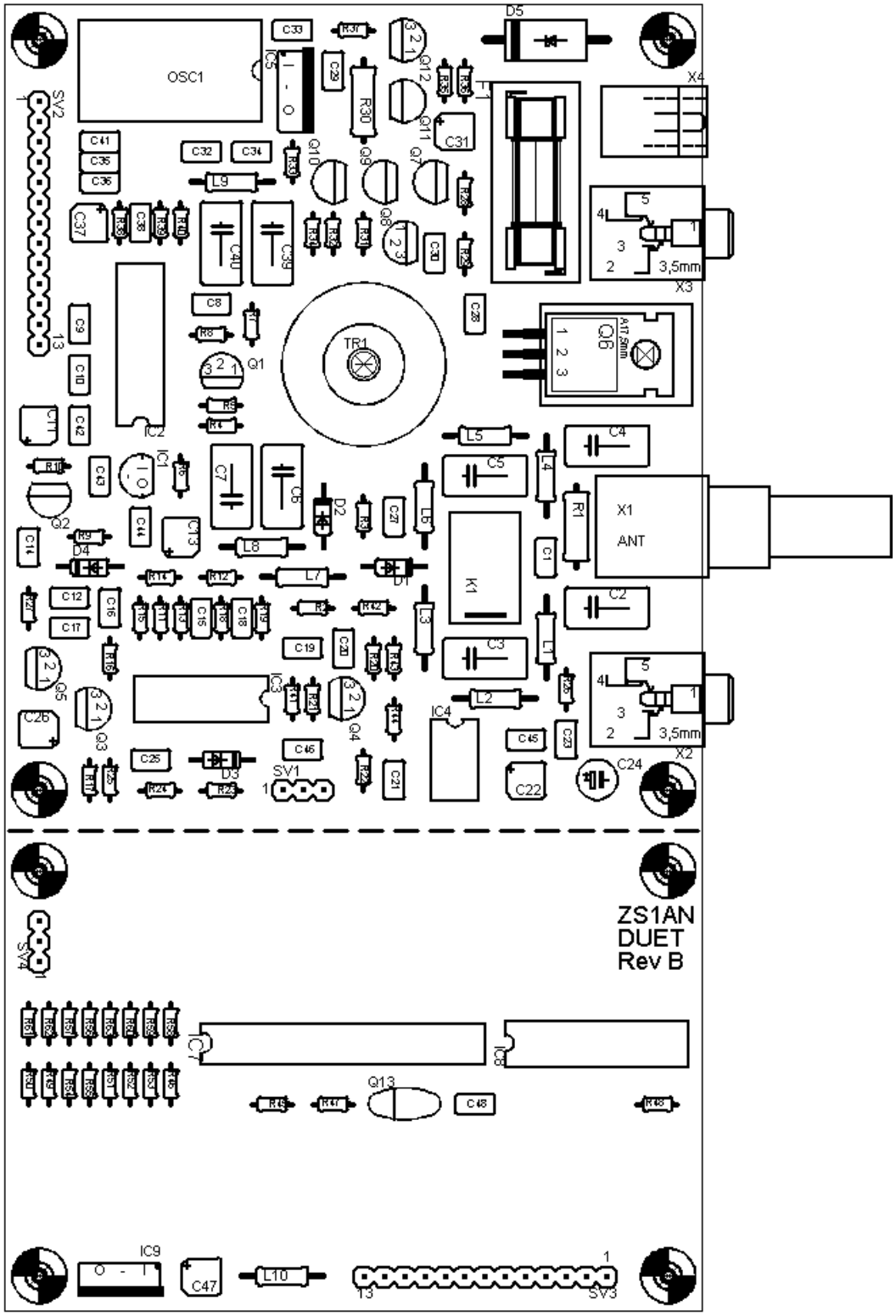

Figure 4 – Parts Placement Diagram (Top of Board)

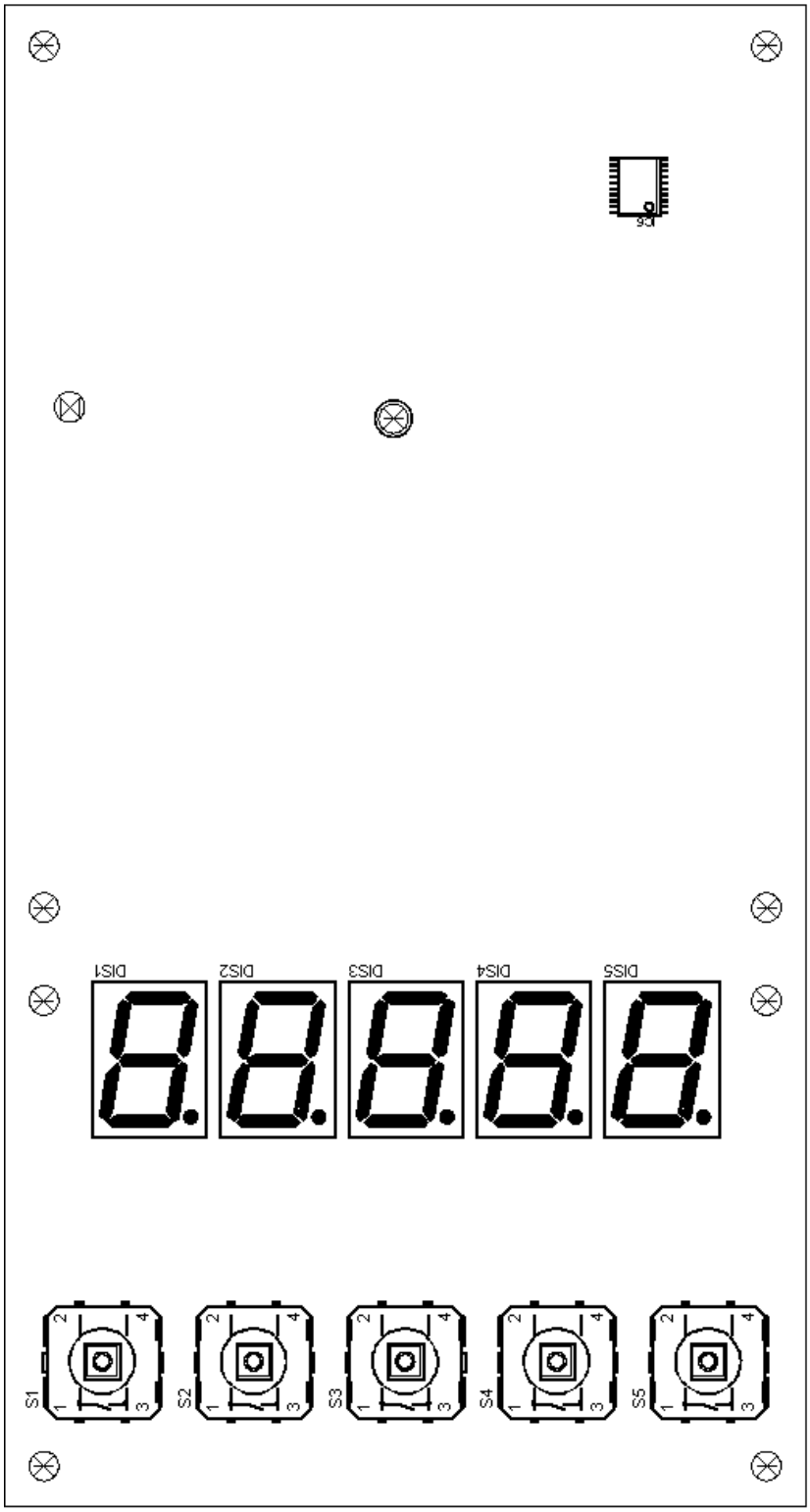

Figure 5 – Parts Placement Diagram (Bottom of Board)

IC7, the PIC microcontroller, should not be soldered directly to the board – rather use a DIP socket, to allow it to be removed and reprogrammed when upgrading the software. All other integrated circuits on both boards may safely be installed without using sockets, provided the soldering temperature does not exceed 350°C and soldering time is limited to about two seconds per lead.

When installing the displays, it is important to ensure that they are seated properly so that the top surfaces are flush, since this will affect the visual appearance of the completed transceiver. I suggest using transparent plastic tape to hold each display in place, and initially soldering just two pins from diagonally opposite corners. Then remove the tape and check that the display is seated correctly before soldering the remaining pins, since it is much easier to correct any problems when only two pins need to be unsoldered. Be sure to mount the displays the correct way round, with the decimal point at the bottom right of the display, as the package is symmetrical and could be fitted upside down.

The push-button switches are not installed so their leads protrude below the PCB like those of the other components. Instead, they are installed so the ends of the leads are just flush with the surface of the far side of the board. This raises the bodies of the switches about 4mm above the PCB, so that they will protrude through the front panel.

Signal Board

On the signal board, IC6 (the AD9834BRU) is a small surface-mounted component that should be soldered to the *bottom* of the board (the side without a silk-screened legend). It should be soldered in place before any of the other parts on the signal board, since it is much easier to solder it while the board can still lie flat. Study the placement diagram carefully to ensure that you get IC6 the right way round – note of the position of the dot that marks pin 1. You can use a thin strip of transparent plastic tape running lengthwise over the top of the package to help position it and then to hold it in place on the board while you solder. I recommend using a magnifying glass to confirm that it is lined up correctly with the pads before you start soldering. It is quite difficult to solder each lead of IC6 individually, since the leads are only ¼ mm thick, with less than ½ mm between leads. Instead, once the IC is correctly aligned, place a drop of solder covering about three of the IC leads, at the end of the leads where they touch the pads on the PCB. Hold the molten solder there for about half a second, so that capillary action draws some of it between the pad and the lead before removing the soldering iron. Then use a solder-sucker to remove the solder blob; it does this effectively but does not remove the solder between the leads and the pads, resulting in a neat and effective solder joint. Remember that once IC6 is in place, you must use anti-static precautions when handling the board, otherwise it could be destroyed by static discharge.

All other parts on the signal board are mounted on the *top* of the board, and positioned according to the silk-screened legend. Be careful to place the polarized capacitors the right way round. Note that some tantalum capacitors have a black line with a tiny "+" sign indicating the positive lead. The "+" sign is easily mistaken for an arrowhead, giving the incorrect impression that the black line indicates the negative lead.

Please note that C50, D6, Q14 and R64-R66 are *not* provided for on the printed circuit board. This will be corrected in the next version of the PCB.

The power MOSFET Q6 must be mounted on its heat sink but separated from the heat sink by an electrically insulating yet thermally conductive washer. If a mica washer is used, then

thermally conductive paste should be applied to both sides of the washer. If a silicone washer is used, then thermal paste is not required. The MOSFET should be bolted to the heat sink and PCB using a non-conductive nut and bolt. The easiest way is to mount the MOSFET to its heat sink with the insulating washer, bolt the assembly to the PC board, and ensure that everything is correctly aligned before soldering the MOSFET leads to the PC board.

Transformer TR1 consists of 15 bifilar turns of 0.5mm diameter enameled copper wire wound on an MS080125-2 toroidal ferrite core (outside diameter 20mm, permeability 125u). Cut two 40cm lengths of 0.5mm diameter enameled copper wire and place them side-by-side. Bind the lengths together every 15mm using a thin (2mm wide) strip of masking tape. Wind 15 turns of the parallel conductor pair around the toroidal core (the number of turns is the number of times the twin conductor goes through the hole in the centre of the core). Be careful to ensure that the bifilar pair is not twisted, as this may cause the transformer to be wired incorrectly. Cut the leads to length, and remove the enamel from the end of the leads carefully using a needle file before soldering the transformer in place.

Mount a 2A quick-blow fuse in fuse holder F1.

Interconnections Between Boards

Figure 6 shows how the two boards are interconnected, and how the two variable resistors are connected to the boards. Although drawn as a schematic, the position and orientation of the connectors corresponds to their position and orientation on the printed circuit boards. Both boards are seen from the top, i.e. from the side with the silk screened component placement legend (remember that the seven-segment displays and push buttons are mounted on the *bottom* of the control board).

The control board is connected to the signal board via the 13-pin connectors SV1 and SV2. The boards are laid out so the connecting cable is wired "straight-through". Use 13 equal lengths of stranded hook-up wire to make up the connecting cable. Be careful to ensure that you put the plugs on the right way round to match the connectors on the boards.

The potentiometers are connected to the boards via 3-pin connectors. In both cases pin 1 of the connector (marked "CW" on the schematic) is connected to the terminal of the potentiometer that the wiper is nearest when the potentiometer is turned fully clockwise. Pin 2 of the connector (marked "CCW") is connected to the terminal of the potentiometer that the wiper is nearest when the potentiometer is turned fully counterclockwise. Pin 3 is connected to the wiper of the potentiometer. The potentiometer should be connected using shielded twin-core cable, with the shield carrying the "CCW" signal (from pin 2).

VR1 is the audio gain control, and should have a logarithmic (or "audio") taper. Note that capacitor C49 should be soldered directly to the "CW" connection of the variable resistor. VR2 is the tuning control, and should have a linear taper.

Software

The PIC microcontroller used in the "Duet" must be programmed with the software needed to control the transceiver. Programmed microcontrollers are available from the author, who may be contacted via email at zs1an@qsl.net.

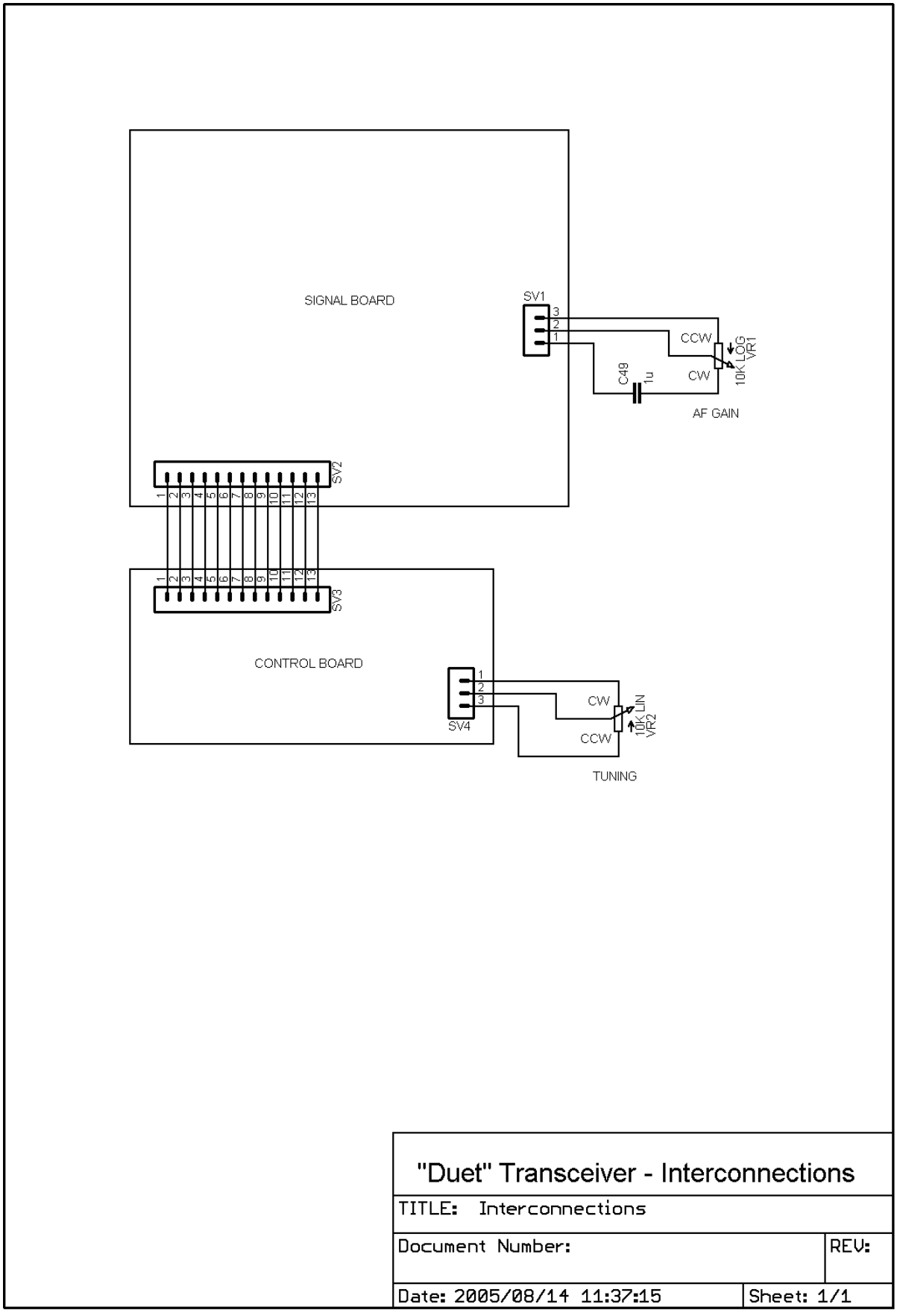

Figure 6 – Interconnections between the control board and signal board

Operation

All controls are mounted on the front panel. Figure 7 shows the front panel layout.

Figure 7 - Front Panel Layout

The "Duet" is controlled using five push buttons and two potentiometers, all of which are mounted on the front panel. Each of the push buttons has two functions. One of the functions is selected by "tapping" the button – that is, pushing it briefly, for less than half a second. The other function is selected by "holding" the button – that is, pushing it and holding it depressed for longer than half a second.

Functions Accessed by Tapping Buttons

These functions are accessed by briefly pushing one of the buttons, and releasing it immediately. They are, from left to right:

BAND Tapping this button toggles between the 40m and 20m bands. The bands have independent frequency registers (VFOs), so when you change to a band the frequency will be set to the last frequency that you used on that band. The "split" and "CW reverse" settings are also retained independently for each band.

SPEED This label refers to the two buttons under it, which control the speed of the CW keyer. Pushing the first of these (the one under the left-hand side of the SPEED label) reduces the speed of the keyer, while pushing the second increases the speed. In both cases the new speed, in words per minute, is displayed for one second. The following speeds can be chosen: 5, 6, 8, 10, 12, 15, 18, 20, 23, 25, 27, 30, 33 and 38 words per minute.

DIS ("Display") If the transceiver is not operating in "split" mode, then tapping this button toggles the receiver display between the operating frequency and the S-meter. The S-meter reading is shown by the number of vertical bars that are illuminated on the display, from zero bars when there is no signal, to nine bars when the signal strength is S-9.

When the transceiver is operating in "split" mode, tapping this buttons toggles the display between displaying the receive frequency and the transmit frequency. Which frequency is currently being shown is indicated by which of two decimal points is illuminated on the display. If the decimal point after the third display digit is illuminated, then the transmit frequency is displayed. If the decimal point after the fourth digit is illuminated, then the receive frequency is displayed. If neither of these decimal points is illuminated, then the transceiver is not operating in "split" mode.

REV ("Reverse") Tapping this button toggles the receiver between "normal" and "reverse" CW reception. In normal reception, the local oscillator is set to a frequency 500 Hz *below* the received signal. In reverse mode, the local oscillator is set to a frequency 500 Hz *above* the received signal. Both modes will generate a 500 Hz sidetone when the signal being received is correctly tuned. If you find that you are receiving interference from an image signal then it may help to change from normal to reverse mode or vice-versa. When the receiver is in "CW reverse" mode the decimal point following the last display digit is illuminated.

Functions Accessed by Holding Buttons

These functions are accessed by pushing the button, and holding it depressed for at least half a second, until the function activates.

ON Holding the button toggles the transceiver between operate and standby mode, which is similar to an on/off switch. In standby mode, the transceiver's display is off, the audio output is muted and none of the control functions except the standby button are operational, so the transceiver is effectively "off". However please note that it still draws some current while in standby mode, so if you are operating from a battery then it is advisable to disconnect the battery when the transceiver is not in use.

TX Holding this buttons enables or disables the transmitter. When the transmitter is disabled, the word "Off" is displayed for one second. When it is enabled, the word "On" is displayed for one second. When the transmitter is disabled, everything works normally including the transmit/receive switching and the sidetone, but the RF power amplifier is disabled so no signal is actually transmitted. This is useful for setting the keyer speed or exploring the transceiver's functions without actually transmitting.

You can tell when the transceiver is actually transmitting by observing the decimal point after the second display digit. This is illuminated when the transceiver is in transmit mode and transmit is enabled.

TUN ("Tune") Holding this button activates the transmitter and generates a continuous output signal for 30 seconds or until the button is pushed and held again. This is intended for use when adjusting an antenna-tuning unit. Note that if transmit has been disabled, then no signal will be transmitted although the sidetone will be turned on.

SPL ("Split") Holding this button activates or deactivates "Split" mode. When "split" mode is activated, both the transmit and receive frequencies are initially set to the same frequency, but they can be tuned independently. The frequency that is tuned is the frequency that is currently being shown on the display. When "split" mode is disabled, both the transmit and the receive frequency are set to the frequency that is currently shown on the display, which could be either the transmit or the receive frequency.

SP ("Spot") Holding this button activates the sidetone, without transmitting or muting the receiver. This allows you to accurately tune the signal, by adjusting it until the pitch of the received signal is the same as that of the sidetone.

Rotary Controls

These are mounted on the right-hand side of the front panel.

GAIN The AF Gain control adjusts the volume of the received signal. It does not affect the volume of the sidetone, which is fixed according to the value of R43 on the signal board.

TUNE The tuning knob operates slightly differently than on most transceivers, since shaft encoders are too expensive for a budget design. Instead a potentiometer is used for the tuning control. When the control is set in the centre, the frequency remains constant. When the tune control is moved right of centre, the frequency starts scanning upwards, with the rate of scanning depending on how far from centre the control is moved. When the tuning control is moved left of centre, the frequency starts scanning downwards, and again the scanning rate depends on how far left of centre the control is moved. There is a large "dead spot" in the centre, making it easy to set the control so the frequency remains constant. Note that the "scan" must be manually stopped when a signal is found, as it does not stop automatically.

Rear Panel Connections

Figure 8 shows the rear panel which has connectors for the power supply, antenna, headphones and paddle or straight key.

Figure 8 – Rear Panel Layout

The connectors are, from left to right:

PHONES A 3.5mm stereo jack socket for headphones.

ANT A BNC connector for a 50Ω antenna.

KEY A stereo 3.5 mm jack socket for a paddle (single-lever or iambic), straight key or bug. On switching from standby to normal operating mode the transceiver automatically detects whether a stereo or mono jack plug is inserted into the socket, and enables or disables the internal keyer accordingly.

13.8 V An MJ-179 connector for connection to an external 13.8 V supply. This is the type of connector commonly supplied on mains adapters. The centre connector should be positive and the outside of the barrel negative. The maximum voltage allowed is 15 V, and applying a voltage higher than this may damage the transceiver. The transceiver incorporates reverse polarity protection as well as a 2A fuse.

Project Cost

At the time of construction of the prototype, the complete set of parts for the transceiver (excluding printed circuit board) was priced from local suppliers for a total of R 364.61 excluding VAT. The PCB would cost R 56.40 to manufacture in quantities of 50, according to a quotation from North Tech Services[3]. The total for parts and PCB would be R 479.95 including VAT.

[3] www.ntspcb.co.za

Appendix A – Specifications

General	
Frequency coverage	7.000 – 7.099 MHz
	14.000 – 14.349 MHz
Mode	CW
Antenna	50Ω unbalanced, BNC connector.
Power supply requirement	12-15V DC
Power Consumption	
Transmit	2A
Receive	250 mA
Standby	150 mA
Transmitter	
Frequency Stability:	50 p.p.m.
Output Power:	10W (40m band)
	5W (20m band)
Spurious Emissions:	-35 dBc
Keyer speed	5 – 38 wpm
Receiver	
Audio Output Power	250 mW at 5% THD

Appendix B - Parts List

Description	Value	Designations	Qty
7-Segment LED Display CC 12.5mm DP right	SC05-11GWA	DIS1, DIS2, DIS3, DIS4, DIS5	5
Capacitor, Ceramic, 2.5 mm pitch	100p	C50	1
Capacitor, Ceramic, 2.5 mm pitch	10n	C8, C17, C20, C32, C36	5
Capacitor, Ceramic, 2.5 mm pitch	22n	C14, C18	2
Capacitor, Ceramic, 2.5 mm pitch	100n	C1, C12, C15, C21, C23, C27, C28, C29, C30, C34, C35, C38, C41, C42, C44, C45, C46, C48	18
Capacitor, Ceramic, 2.5 mm pitch	220n	C9, C10	2
Capacitor, Ceramic, 2.5 mm pitch	470n	C16, C19, C25, C33, C43	5
Capacitor, Elecrolytic, 16V, 5mm pitch	100u	C24	1
Capacitor, Polyester	1u	C49	1
Capacitor, Polystyrene 2.5% 160 V, miniature radial	47p	C40	1
Capacitor, Polystyrene 2.5% 160 V, miniature radial	68p	C39	1
Capacitor, Polystyrene 2.5% 160 V, miniature radial	220p	C2, C3	2
Capacitor, Polystyrene 2.5% 160 V, miniature radial	330p	C6, C7	2
Capacitor, Polystyrene 2.5% 160 V, miniature radial	470p	C4, C5	2
Capacitor, Tant 16V, 2.5mm pitch	10u	C11, C13, C22, C26, C31, C37, C47	7
Ceramic Resonator, Murata CST4.00MGW	4 MHz	Q13	1
Connector, 3.5 mm Jack socket, Stereo, PCB Mount		X2, X3	2
Connector MJ-179 PCB Mount		X4	1
Connector, Coax BNC, PCB Mount Right-Angle	50 ohm	X1	1
Connector, pin header socket, 3 pin		SV1, SV4	2
Connector, pin header socket, 13 pin		SV2, SV3	2
Connector, pin header plug, 3 pin		SV1, SV4	2
Connector, pin header plug, 13 pin		SV2, SV3	2
Crystal Oscillator Module, MO-12B-50M	50 MHz	OSC1	1
Diode, Schottky Rectifier 3A	1N5822	D5	1
Diode, Signal	1N4148	D1, D2, D3, D4, D6	5
Ferrite toroid 125u OD 21.1 ID 12.1		TR1	1
Fuse holder, PCB mount, 20mm		F1	1
Fuse, Quick blow, 20mm	2 A	F1	1
Heatsink, TO-220, with mounting kit		Q6	1
IC, Audio Amplifier	LM386N-1	IC4	1
IC, CMOS	74HC4053	IC2	1
IC, Darlington Driver	ULN2803A	IC8	1
IC, DDS	AD9834BRU	IC6	1
IC, Op Amp	TL074CN	IC3	1
IC, PIC Microcontroller	PIC16F872-I/SP	IC7	1
IC, Voltage Regulator	7805	IC5, IC9	2
IC, Voltage Regulator	78L09	IC1	1
RF Choke	1uH	L1, L3	2
RF Choke	1.2uH	L8	1
RF Choke	1.5uH	L2, L4, L6	3
RF Choke	2.2uH	L5	1
RF Choke	2.7uH	L9	1
RF Choke	100uH	L7	1
RF Choke	1mH	L10	1
Potentiometer, Linear, panel mount	10k	VR1	1
Potentiometer, Log, panel mount	10k	VR2	1

Description	Value	Designations	Qty
Relay, DPDT, 12V Coil	Nais TQ2-12V	K1	1
Resistor, 125mW, 5%	10	R7, R26, R43	3
Resistor, 125mW, 5%	47	R31	1
Resistor, 125mW, 5%	100	R8	1
Resistor, 125mW, 5%	150	R56, R57, R58, R59, R60, R61, R62, R63	8
Resistor, 125mW, 5%	180	R32	1
Resistor, 125mW, 5%	200	R39, R40	2
Resistor, 125mW, 5%	470	R2, R29	2
Resistor, 125mW, 5%	680	R6	1
Resistor, 125mW, 5%	1k	R3, R13, R28, R35, R36, R65	6
Resistor, 125mW, 5%	1k5	R64	1
Resistor, 125mW, 5%	1k8	R25, R49, R50, R51, R52, R53, R54, R55	8
Resistor, 125mW, 5%	2k7	R5	1
Resistor, 125mW, 5%	4k7	R41, R34	2
Resistor, 125mW, 5%	5k6	R4	1
Resistor, 125mW, 5%	6k8	R10, R36	2
Resistor, 125mW, 5%	10k	R12, R14, R27, R33, R37, R42, R45, R46, R47, R48, R66	11
Resistor, 125mW, 5%	15k	R9, R18	2
Resistor, 125mW, 5%	47k	R22, R23, R33, R44	4
Resistor, 125mW, 5%	100k	R11, R15, R16, R17, R19, R20, R21	7
Resistor, 125mW, 5%	4M7	R24	1
Resistor, 0.5 W, 5%	120	R30	1
Resistor, 0.5 W, 5%	1k	R1	1
Socket DIP 28-pin 0.3"		IC7	1
Switch, PCB Mount, momentary, SPST N/O	RAC0N12	S1, S2, S3, S4, S5	5
Switch, PCB Mount, Cap		S1, S2, S3, S4, S5	5
Transistor, J-FET, P-Channel	2N3820	Q3, Q4	2
Transistor, Power MOSFET, N-Channel	IRF510	Q6	1
Transistor, NPN, general purpose	2N3904	Q7, Q9, Q10, Q11	4
Transistor, NPN, low-noise audio	BC549B	Q2	1
Transistor, NPN, RF	BF199	Q1	1
Transistor, PNP, general purpose	2N3906	Q5, Q8, Q12, Q14	4