The DSP-610 Transceiver
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I recently saw a QST QuickStats page which revealed that most ARRL members think that it's more difficult to homebrew amateur radio equipment now than was in the past. Since I don't feel that way, I can only guess that most homebrewers are not yet comfortable with using surface-mount technology. Having been involved with homebrew projects for more than 30 years, I think that it's easier than ever. The range of high quality components, sophisticated digital devices, low-cost microprocessors and PCB fabrication services mean that hams can build in a level of sophistication into homebrew equipment that would not have been possible five years ago and not even imaginable 10 years ago.

Enter the DSP-610 transceiver; designed for the 3rd ARRL Homebrew Challenge. The total price for all materials is under $200 but it includes:

♦ A digital signal processor (DSP) running 40 million instruction per second (MIPS) which digitally performs all function from the 2nd IF onward.

♦ A fractional-N synthesizer running in the microwave frequency spectrum, divided down with high-speed digital dividers for an ultra-low phase noise 1st local oscillator (LO).

♦ A direct digital synthesizer (DDS) for the 2nd LO.

♦ A monolithic microwave integrated circuit (MMIC) amplifier in the TX drive chain.

♦Gallium arsenide RF integrated circuits (RFIC) for low level RF/IF switching.

All of this technology is available for a few dollars, fully integrated, so you don't need a Master's degree in engineering to use it, all you need is a good pair of tweezers and a magnifying glass.

Transceiver Specifications

The Homebrew Challenge III issued by the ARRL last year is to build a 25 watt, SSB/CW transceiver that covers either the 10 meter band, the 6 meter band or both. The following technical criteria are listed on the ARRL website:

♦Frequency coverage;
10 meters, 28.0 through 28.6 MHz or greater;
6 meters, 50.0 through 50.25 MHz or greater.

♦ Frequency readout (mechanical or electronic) resolution: less than 1 kHz.

♦ Receiver noise figure: 10 meters, less than 8 dB; 6 meters, less than 5 dB.

♦ Receiver selectivity maximum: 3 kHz at 6 dB.

♦ Receiver audio output: minimum; 0.5 W minimum with less than 10% distortion.

♦ Transmitter must meet all FCC requirements.

♦ TR switching; CW, semi or full break-in operation; Voice, VOX or push-to-talk

♦ Mic sensitivity; Adjustable, with full 25 W output from standard low impedance dynamic mic or equivalent.

♦ Output of 25 W into 50 W load with up to 2:1 SWR for at least 30 seconds. No damage driving open or short at antenna jack for 30 seconds.

♦ Power required: either 120 V ac, 60 Hz mains or nominal 13.8 V dc supply.

The DSP-610 goes beyond these requirements in a few areas;

♦ The frequency coverage includes the 12 meter band as well as 6 and 10 meters. Covering 24.5

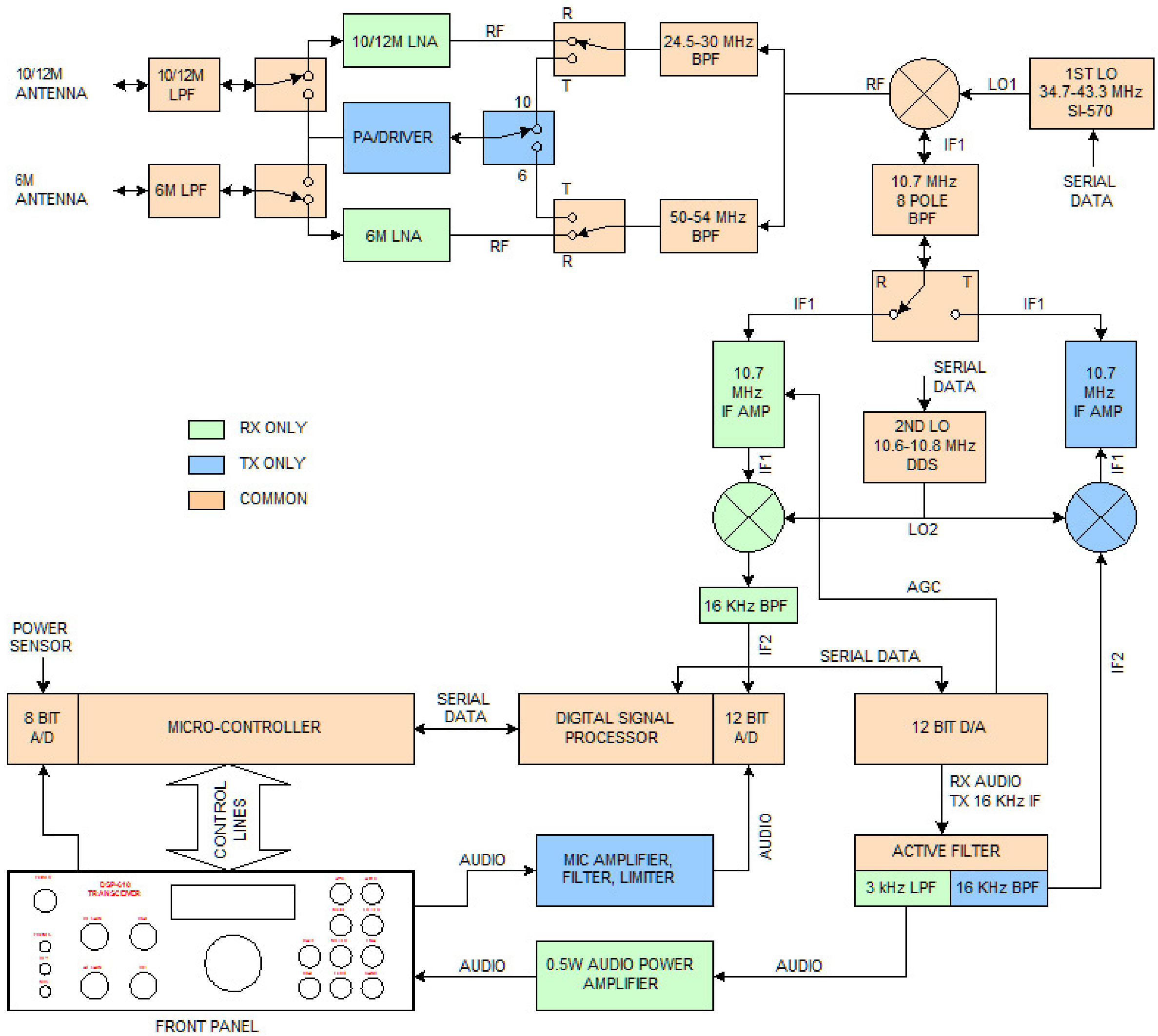

Figure 1: DSP-610 Block Diagram

to 25.13 MHz, 28.0 to 28.63 MHz and 50.0 to 50.63 MHz

♦ A frequency synthesizer provides 10Hz frequency resolution with 10Hz, 100Hz and 1 kHz tuning steps with the operating frequency displayed to 10Hz.

♦ A and B VFO on each band that stores operating mode and bandwidth.

♦ An IF digital signal processor with 0.4, 0.6, 0.8, 1.0, 1.8, 2.0, 2.2, and 2.4 kHz bandwidths, passband tuning and digitally controlled AGC.

♦ Receive S meter and transmit forward/reflected power meter.

Design

Figure 1 shows the block diagram of the DSP-610. The transceivers uses a dual-conversion super-heterodyne architecture with the first IF at 10.7 MHz and the second at 16 kHz. The first local oscillator (LO) signal, derived from a Silicon Labs SI-570 oscillator, is tuned 10.7 MHz above the RF signal on 10 and 12 meters and 10.7 MHz below the RF signal on 6 meters. An Analog Devices AD-9833 direct digital synthesizer generates the second LO and the BFO is a numerically control oscillator implemented in the DSP.

Receiver

In receive mode, the incoming signal is passed through the high power lowpass filter then switched into a low noise amplifier (LNA) using electromechanical reed relays. The LNA uses the BF-998 dual-gate metal oxide semiconductor field-effect transistor MOSFET in a design that dates back to the 1970's. To keep the noise figure as low as possible, the main RF filtering comes after the LNA's with a 3 pole coupled resonator filter on 6 meter and a 2 pole filter for 10/12 meters. The signal is then converted to the 10.7 first IF using the venerable SBL-1 double balanced mixer from Mini Circuits. The 8 pole crystal roofing filter comes right after the mixer and is about 6 kHz wide. Another 3 BF-998's provide 2 IF gain stages and the 2nd mixer respectively. The AGC voltage is applied to the two amplifier stages.

After the 2nd mixer and active operation amplifier (OPAMP) filter is used for anti-aliasing and impedance matching for the input of the analog to digital (A/D) converter. The A/D converter, which is integral to the Microchip DSP, samples the 2nd IF 50,000 times per second with 12 bits of resolution. The DSP applies the input samples to one of eight, 127 tap finite impulse response (FIR) filters to set the IF bandwidth. The DSP also detects the signal level, generates the automatic gain control (AGC) signal for the IF amplifiers, performs a product detection algorithm and low pass filters the recovered audio. A separate digital to analog (D/A) is used to convert the signal to an audio signal which is filtered by an active OPAMP low pass filter then amplifier to speaker volume with a 0.75 watt audio amplifier chip.

Transmitter

Audio from the microphone is amplifier, filtered and limited in two OPAMP stages. The audio is then presented to the A/D converter that produces 50,000 samples per second with 12 bit resolution. The audio level is adjusted digitally, hard limited, lowpass filtered and multiplied with the output of a numerically controlled oscillator (NCO) to produce a double-sideband suppressed carrier which is sent through a 2.2 kHz FIR filter then to the D/A converter. In CW mode the NCO generates the 2 IF signal directly as well as an adjustable sidetone signal.

The 2nd IF signal is converted to the 10.7 MHx 1st IF using a SA 604 mixer chip, amplified passed through the 8 pole roofing filter backwards. The SBL-1 then converts the 1st IF to the RF frequency. Four stages of RF amplifier are used to bring the output to 25 watts. The output stage is similar to the 50 watt amplifier that I designed for the HBC II as is the directional coupler that is used to display the forward and reflected power. Two 5-pole lowpass filters, one for 10/12 meter and one for 6 meters, reduce the harmonic level to meet FCC requirements.

Processing

The DSP-610 has two microprocessors; a general purpose processor (GPP) and a disital signal processor (DSP). The GPP, a Microchip 18 series PIC, handles most of the housekeeping tasks like running the front panel, toggling singles between bands and operating modes, controlling the LO's and storing operating parameters in nonvolatile memory. The DSP, a Microchip 33 series dsPIC, handles the transmit and receive signal processing as described above. The DSP runs at 40 MIPS which translated to 800 instructions per sample at a 50 Khz sample rate. Due to limitations in

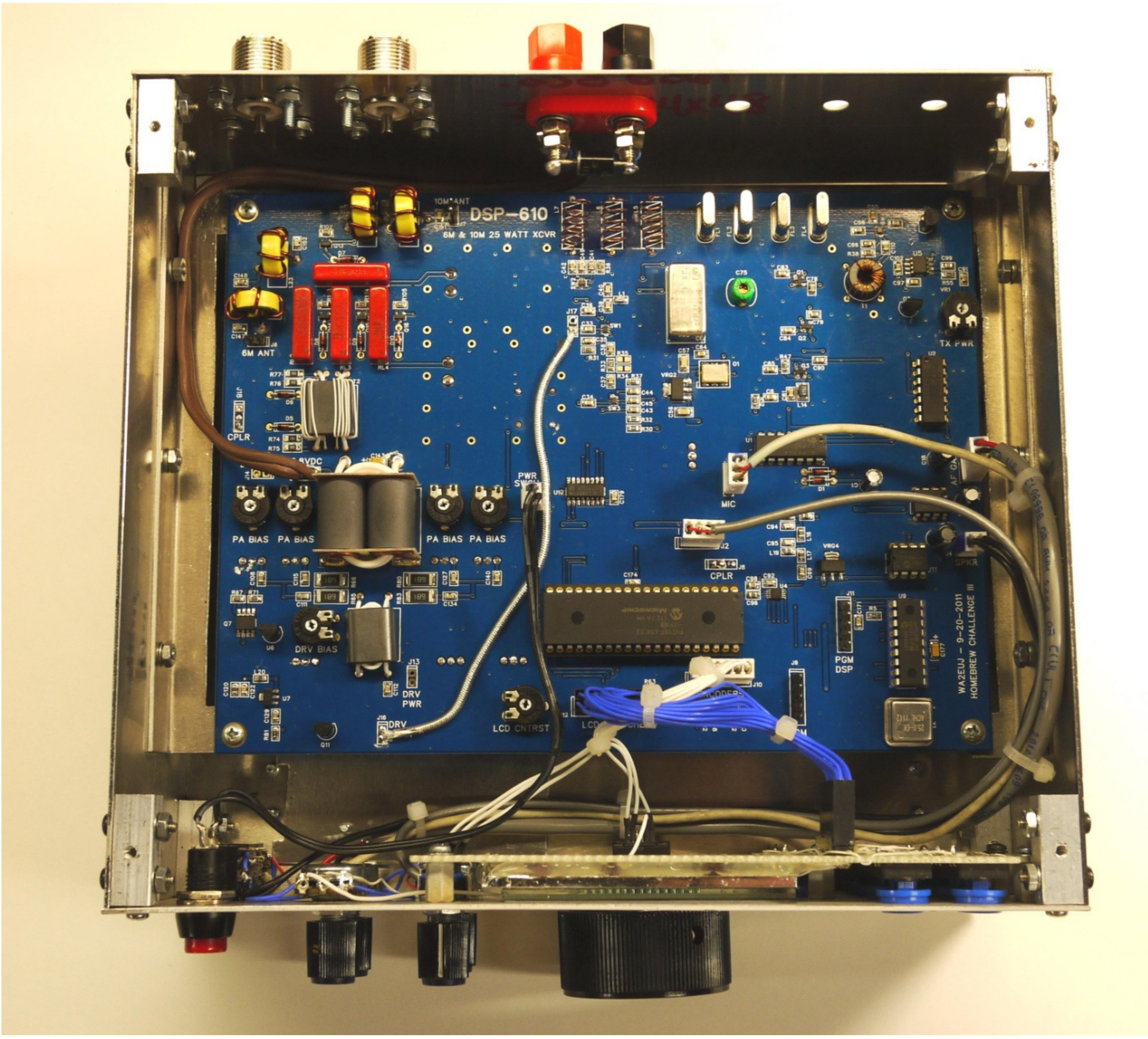

Figure 2: DSP-610 Constrction

memory the FIR filters are limited to 127 taps and since the DSP can perform each tap in a single clock cycle there's plenty of time left over for the NCO, AGC and other tasks. If I had it to do over I might have selected a dsPIC with more memory because 255 or 511 taps would provide more aggressive filtering but I was under the erroneous impression that the processor would run out of time first. All of the processing elements derive their clocks from a single 25 MHz clock to help reduce internally generated spurious signals. The 25 MHz value was chosen because the fundamental (25 MHz) can be toned in the 10/12 meter band and the 2nd harmonic (50 MHz) can be tuned in the 6 meter band which created a built-in signal generator for tweaking the LNA's and IF interstage tuned circuits.

Construction

The DSP-610 is constructed with most of the components mounted on a double sided printed circuit board (PCB). There are services on the internet which allow a circuit designer to buy prototype quantities of a PCB and the company will offer additional copies of the PCB for sale. The PCB for the DSP-610 was made by HobbyPCB.com and is a high quality PCB with soldermask, silk screen and emersion gold plating for easy soldering. HobbyPCB sells the PCB for $20. The schematics, bill of material (BOM), PCB design files, source code and other documentation is available for download front the QST binaries site.

There is a total of 494 parts on the BOM almost half of them are capacitors. The majority of the components are surface mount and most of them are big enough that they are not too difficult to handle. There have been numerous articles in QST dealing with surface mount assembly techniques so assembling the DSP-610 should not be out of range of the intermediate to advanced homebrewer. The BOM also includes the required chassis components to assemble a chassis similar to the one shown in figure 2. The heat generating components are mounted on the back of the PCB and connected to the bottom of the chassis with an aluminum bracket made from pieces left over from the chassis.

Prior to producing the design files for the PCB, I constructed each individual stage separately using standard prototyping techniques with mainly through-hole components. Testing and fine tuning is much easier with this type of assembly. Once I got the entire radio working satisfactorily, I recorded the schematic and designed the PCB. Assembling the PCB, I went section by section starting with the microprocessors, then the receiver, then the transmitter and power amplifier.

When I fired up the power amplifier, the entire radio stopped working, RF was getting everywhere. To make matters worse, the PA chain has more than 60 dB gain to get the -15 dBm signal from the mixer to the required +44 dBm signal at the antenna port. The output was feeding back into the input and every extraneous signal in the radio was amplified and sent out the antenna. Fortunately, with the help of Bob Allison at the ARRL test facility, and some left over aluminum from the chassis, I was able to create an internal shield between the PA and the other circuitry which greatly reduced the spurious emissions and feedback.

Get the Iron Warmed Up

With today's components and assembly techniques, it is possible for the modern homebrewer to build equipment with all of the features of the commercial units. Best of all you can customize the unit anyway you like; choose the layout of the controls, build it for different bands, reprogram the processors for additional features anything goes.

Acknowledgements

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Biography

ARRL member and Extra class licensee Jim Veatch, WA2EUJ received his first call sign in 1976. He is an avid kit builder and homebrewer and enjoys experimenting with applying new technology to Amateur Radio projects. Jim holds an Associates Degree an Electronic Technology as well as a Bachelor's of Science in Electrical Engineering. He has spent his professional career engineering air-ground HF/VHF communications sites for Aeronautical Radio, direction finding systems for L3 Communications and lately software defined radios for Lockheed Martin. Jim can be reached at 1704 Bolton St, Baltimore, MD 21217 or on email at WA2EUJ@arrl.org.