The DSPx: An Experimenter's Module for Digital Signal Processing

By Lyle Johnson, KK7P

Background

There has been interest in applying digital signal processing (DSP) techniques to Amateur radio for more than a decade.

In the early 90's, AMSAT and TAPR teamed to produce a standalone external unit, the DSP-93. This kit provided advanced filtering and modems. Its cost was high, and a later effort was made to incorporate the Motorola DSP56002 Evaluation Module (EVM) into a similar enclosure. This was lower in cost and fairly popular, but Motorola soon discontinued the EVM.

In 1999, Bob Larkin, W7PUA published his DSP-10 Software Defined Radio articles in QST. This was built around an Analog Devices development board, which sold for only $89. This same board was the basis for all of the DSP experiments in the latest ARRL publication, Experimental Methods in Radio Frequency Design.

Alas! Analog Devices increased the price of the evaluation board from $89 to $245, and has all but discontinued it in favor of more current technology.

During the late 90's, soundcards began to appear in personal computers. Today, it is difficult to find a PC without a soundcard. And modern PC processors include DSP instructions which execute at incredibly fast rates. This has resulted in an explosion of available software to use the soundcard in conjunction with a radio to perform DSP tasks. Witness the explosion in popularity of "soundcard modes" such as PSK31.

What's an experimenter to do?

In December 2002, I took a hard look at available options for DSP experimentation.

What I Found

Inexpensive evaluation boards are no longer available. Typical prices are $179 to $495. Distribution channels are oriented to industrial enterprises, which is to be expected since the evaluation boards are intended to get design wins for an semiconductor manufacturer's products. They are not intended to be mass-produced assemblies.

In many cases the included development software is crippled in some fashion, and the "real" development software often costs as much as $3495.00!

PC based soundcard software is widely available, but often the source code is not. Most of the open-source energy seems to be in the Linux community, and Linux is not the operating system of choice for many Amateurs.

Soundcard software for Windows is a bit of an art, and one still has to deal with the overhead and other issues surrounding Windows. Or become expert in the use of Linux, or other OSes for which soundcards exist.

Soundcards have very mixed results, especially in terms of A/D performance. My experience with the SDR-1000 soon proved to me that the A/D portion of many soundcards leaves much to be desired.

Finally, if one wants to make a small DSP-based device, embedding a PC is not terribly practical. And I wanted to do just that, to add some badly needed functionality to my Elecraft K2 HF transceiver. I just couldn't see trying to squeeze a laptop computer into the diminutive case of the K2, or how it would operate on the K2's internal battery pack!

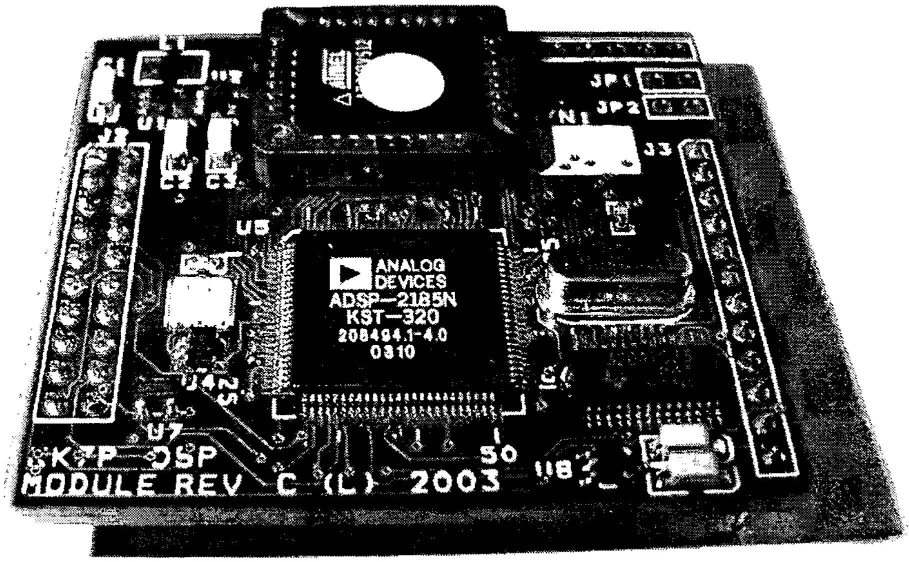
It seemed there was no easy path for embedded DSP experimentation, short of a full-scale product development.

The DSPx is Born

As a result, I decided to make a DSP module especially for experimentation. Such a module could be used in the DSP-10, to support the experiments in the EMRFD book, and be suitable for embedding in various projects.

Such a module would have to be inexpensive, pre-built, have available free development software, and be as compatible as practical with the DSP-10 and EMRFD projects. It would have to be low in power consumption. It would be based on current technology. And it would have to be very easy to incorporate into other projects.

The resulting design was named the DSPx.



It is based on the Analog Devices ADSP-2185N, which is the modern incarnation of the ADSP-2181 used in the DSP-10 and EMRFD projects. The '85N has the advantages of greatly reduced power consumption, 2 ½ times the speed, a smaller footprint and a lower price.

It also includes several bits of digital I/O and a pair of serial expansion ports.

The DSPx includes a dual 16-bit A/D converter with specifications several dB better than the older evaluation board. It has a dual D/A with headphone level amplifier, again with better specs than the old evaluation board. It includes a decoupled bias voltage for an electret microphone. And it supports sampling rates form 4 kHz to 96 kHz. This allows applications with audio, servo feedback, modems and software defined radio experiments.

Naturally, the best low-power CODEC (a device which contains both an A/D and a D/A) was made by a different manufacturer than the DSP chip, and the serial protocols were incompatible. The CODEC, from TI, is the TLV320AIC23. It is designed for portable MP3 players, and as a result has excellent specifications as well as very small power requirements. The required glue logic was implemented in a low power CoolRunner CPLD from Xilinx. The XCR3032XL was designed in to support this interface.

In the end, the DSPx, running at 80 MHz, consumes about 60 mA from a nominal 3.3V source, or about 200 mW. It supports power-save modes which can significantly reduce power consumption if a given application does not require this much processing horsepower.

Finally, the tools are DOS-based, which means they should run in a DOS window under most versions of Windows, as well as DOSEMU under Linux. I have used them under Windows 98, Windows XP Professional - and DOS!

Open Source Software

Don't run away, I am speaking neither of Linux nor of OS religion.

If the DSPx is to be used for experimentation and self education, the source code for the monitor needs to be freely available. And so it is.

I ported most of the experiments from EMRFD to the DSPx and the source code is on my website (www.kk7p.com and follow the links). With the help of Bob Larkin, W7PUA, the DSP-10 code has been ported to and successfully run on the DSPx.

And the source code for the KDSP2 is also open source. The KDSP2 is the first commercial application of the DSPx, and was the personal driver I used to develop the DSPx and measure its usefulness as an embedded DSP.

First Embedded Application

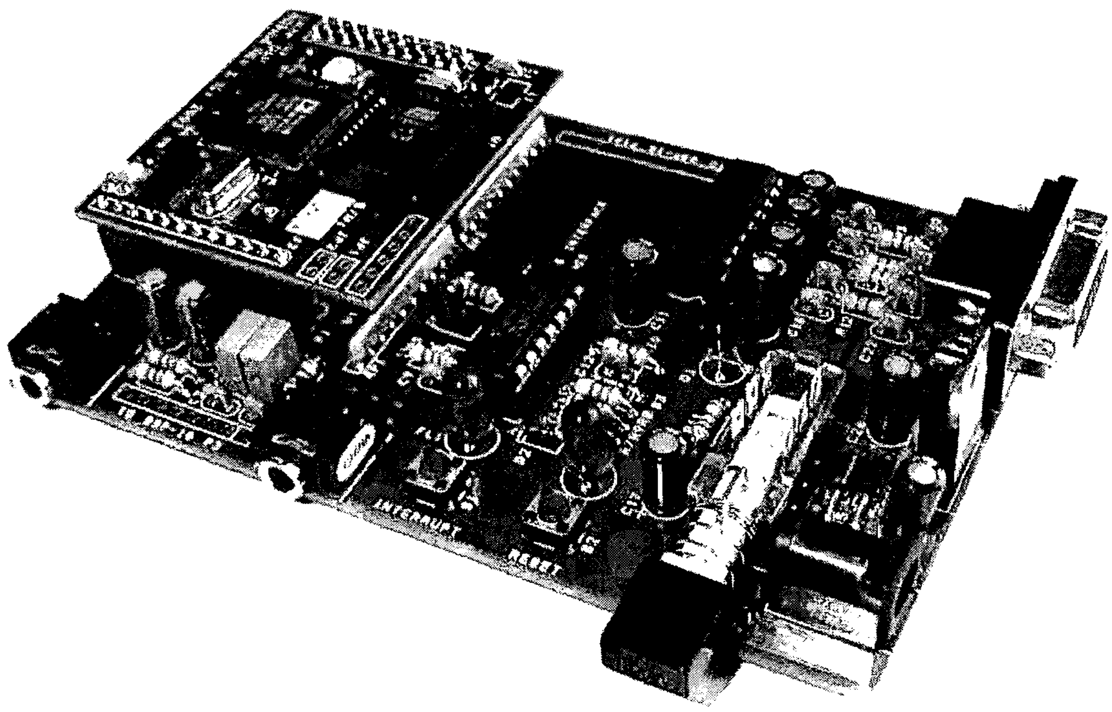
Like thousands of other Amateurs, I own an Elecraft K2 HF transceiver. I noticed that it lacked the common DSP features we take for granted in modern SSB HF radios: autonotch, denoiser, a large selection of filters.
I decided to try and embed the DSPx into the K2.

This turned out to be major investment in effort. I had to decipher the internal inter-processor communications bus, figure out how to take over some of the front panel to allow control of the DSPx, and how to take over the display to provide feedback to the operator.

The end result, however, was well worth it. Elecraft was impressed with the performance of the DSPx, and has incorporated it into their product line. The details of how all this was developed can be found on the web at www.elecraft.com/KDSP2/kdsp2design.pdf.
And perhaps the biggest bonus for experimenters is that several hundred DSPx's have been produced, so the design is debugged and reliable.

KDSP10 Development Platform

In order to develop with the DSPx, it was clear than some sort of adapter module was necessary that would provide power, an RS232-compatible serial port, audio coupling, reset, debounced pushbuttons and an easy way to get at the I/O.

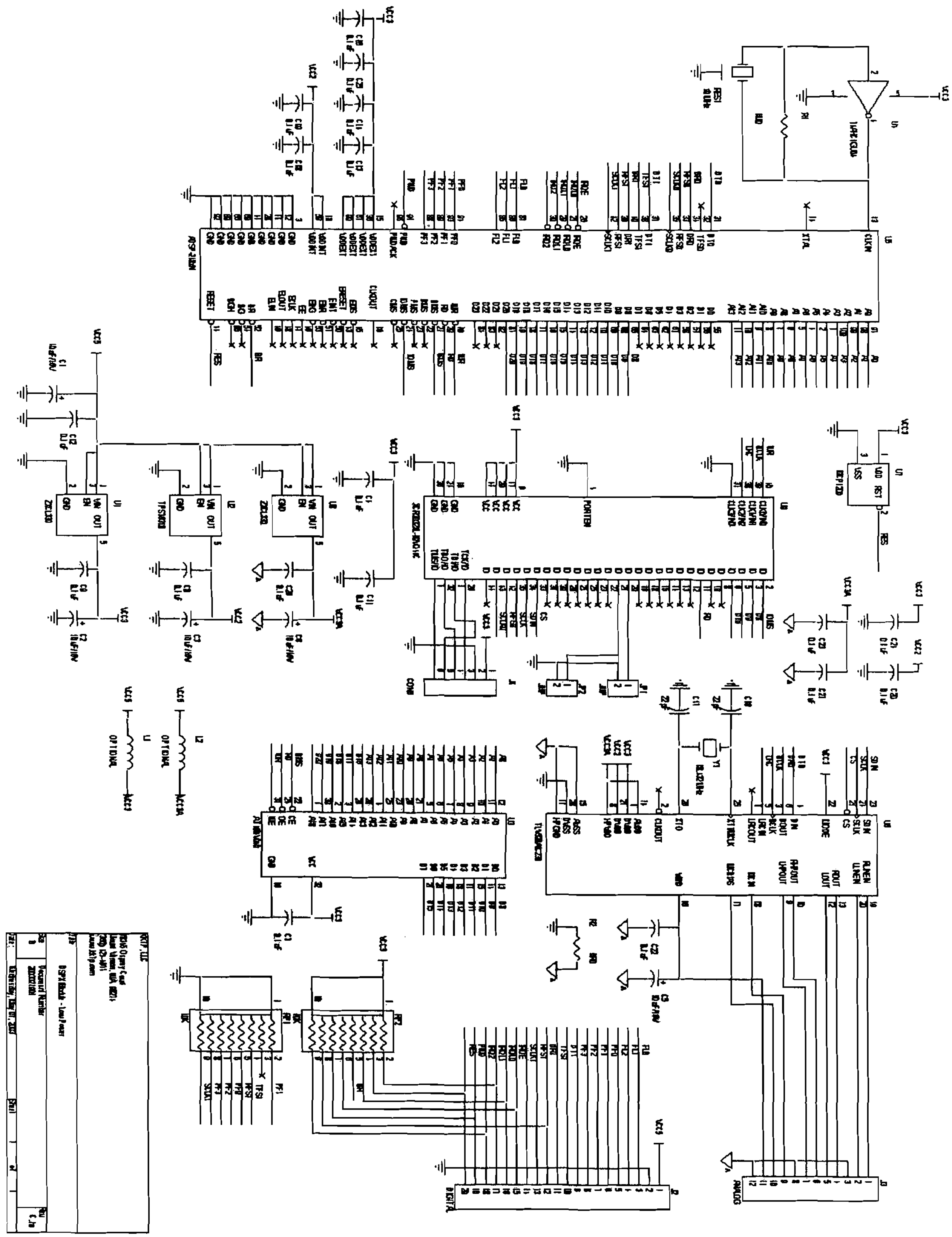


The resulting module, which also provides voltage translation from 3.3.V to 5V for ease of use in the DSP-10, is called the KDSP10. It is available as a kit, or you can simply gather the parts and build it. As with the DSPx, the documentation for the KDSP10 is freely available.

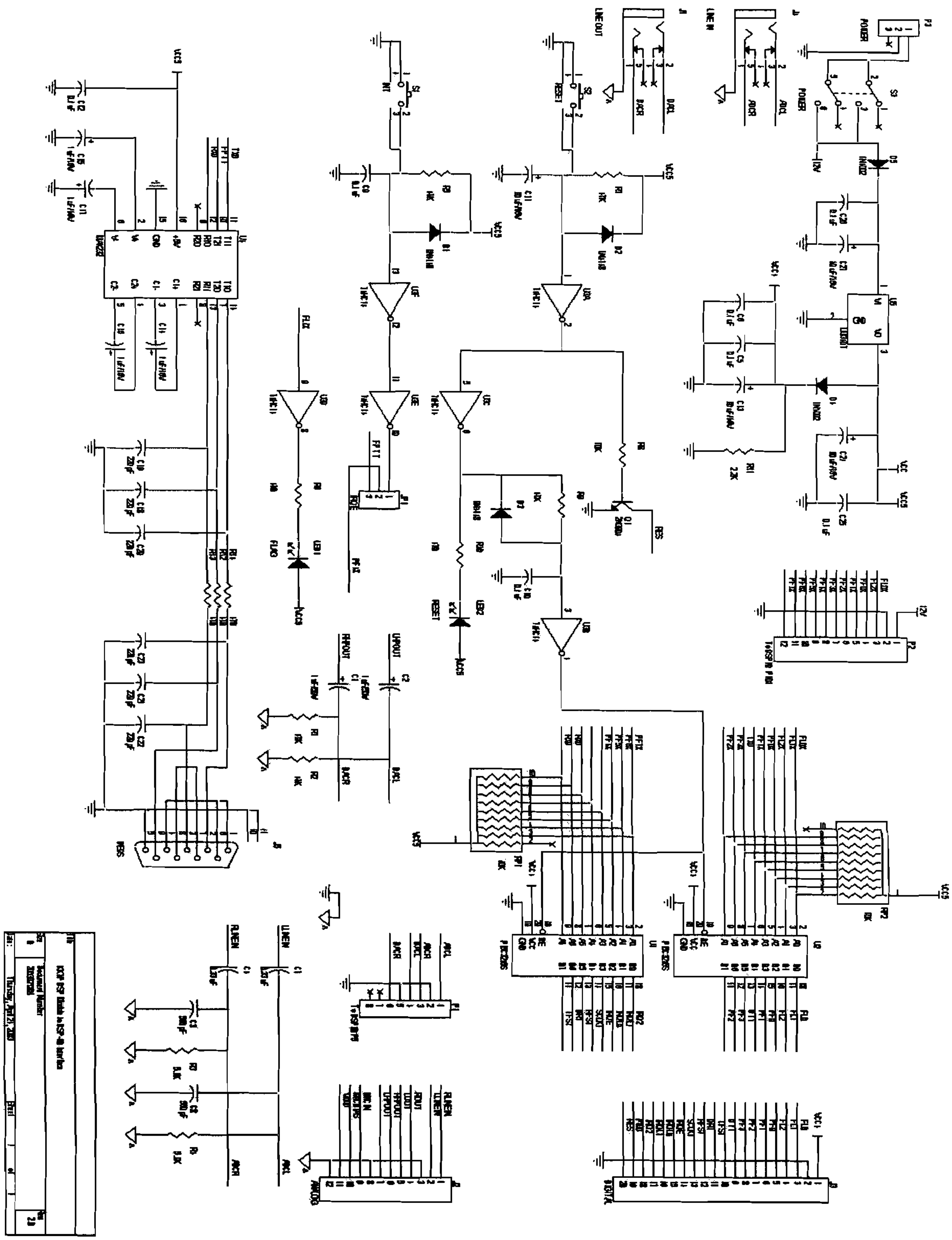
TAPR

When it became apparent that the DSPx was going to work, that the tools were available, and that it would provide the missing piece for the DSP-10, I contacted TAPR to see if they were interested in making it available. Given their incredible dedication to the DSP-10 project, and digital applications in Amateur radio in general, it seemed a good fit.

TAPR graciously agreed to make the DSPx module and KDSP10 kit available, and it was unveiled at the Dayton Hamvention in May, 2003.



DSPx Schematic



KDSP10 Schematic