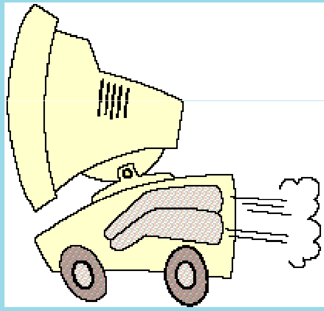
High-speed data acquisition technologies push PC/104 into new markets



By Frank Chase and Don Krenn

New, low-power, high-frequency IC processes coupled with ever shrinking package sizes are allowing high-performance ICs to squeeze into spaces that were inconceivable just a few years ago. At first glance, it might appear that the high-speed data acquisition market has somehow escaped the recent migration of the electronics industry towards smaller, cheaper, and higher-performance products. With the exception of PCI, hardware has changed little in the past five years. We have to look back to the mid-eighties to see the last major shift when much of the rack-mount and tabletop high-speed data acquisition equipment started giving way to cheaper and more powerful ISA board plug-in solutions.

A brief history

Since 1989, when the first ISA bus data acquisition/DSO card was developed, the data acquisition market has grown more than $100 million. And as you might expect, the landscape is once again shifting. This time, PC/104 – with its modular standards and cross-platform potential – is definitely attracting its fair share of new, high-speed designs. This should come as no surprise to the industry. For example, Analog Devices released a 125 MHz DDS (Direct Digital Synthesis) chip called the AD9850 over a year ago, which includes a built in 10-bit DAC and high-speed comparator that fits into a 24-pin SSOP package. It literally takes up less space than your thumbnail.

You can find hundreds of examples of this phenomenon in every area of electronics, including...

- ❏ sensors
- ❏ connectors
- ❏ A/D and D/A converters
- ❏ FPGAs and switching regulators

The desire for small, low-power, high-speed data acquisition equipment is especially strong in the portable markets. From portable instruments for the medical industry to test instruments that field service engineers use on a daily basis, the demand is growing for high-performance, portable data acquisition equipment. Companies that made it big during the transition to the ISA/PCI platforms may end up missing the most exciting and lucrative opportunity of all. While the typical ISA, PCI, CompactPCI, VME, or VXI board will not squeeze into PC/104 applications, the PC/104 modules can easily populate carrier cards that adapt them to other existing platforms. This approach affords the ultimate in backwards compatibility.

Since data acquisition components – even for the high-end – come in a wide range of types including high-speed digital I/O, we will confine our discussion primarily to analog I/O.

High-speed data acquisition

The term “high speed” may seem relative depending on how many bits of resolution your applications require. For simplicity, we are going to define “high speed” as relating to any system with a maximum clock or sampling rate above 1 MHz. Although you can find 16-bit A/D systems already available with sampling rates as high as Megasamples/sec, the prices are completely out of reach for most applications.

For those unfamiliar with speeds of the existing ISA and PCI products, at least a dozen companies offer A/D boards with sample rates of 500 Megasamples/sec or higher. Even more interesting is the fact that 1 GHz PC/104 data acquisition cards should be available by the end of this year, thanks to recent advancements in IC technologies. Furthermore, A/D and D/A with these sampling rates will draw only between 5 and 10 watts – much lower than current competing products in other form factors.

The fastest monolithic 12-bit A/D technology available today is hovering at a maximum of 60 Megasamples/sec, while 10-bit A/D technology has reached 100 Megasamples/sec and is available from many companies. The speed demon of the A/D converters is the 8-bit version, which already reaches 1 Gigasamples/sec. However, if you are looking for an economical solution at a price point that combines the best price with performance, you will have to be satisfied with sampling rates one-fourth to one-tenth times these.

New applications for PC/104

At the lower frequencies of the high-speed analog I/O market (for example from 1 to 50 MHz), we find applications such as those presented below:

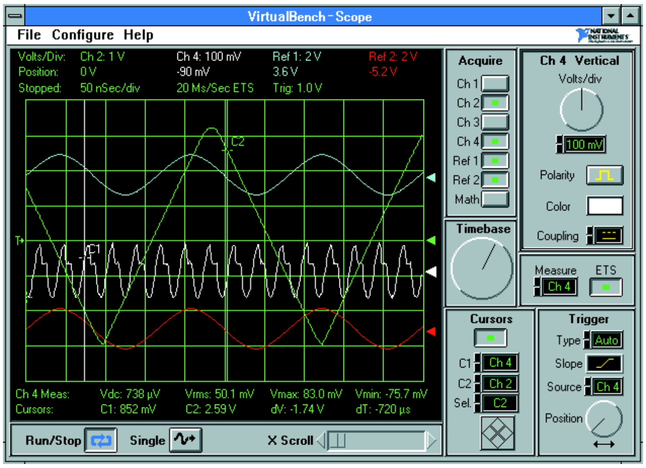
- ❏ high-speed glitch capture
- ❏ explosion testing
- ❏ ultrasonic materials testing
- ❏ automotive testing
- ❏ laser Doppler anemometry
- ❏ spectrum analysis
- ❏ time-of-flight mass spectrometry

Examples of applications at frequencies above 50 MHz are:

- ❏ disk drive testing
- ❏ LIDAR

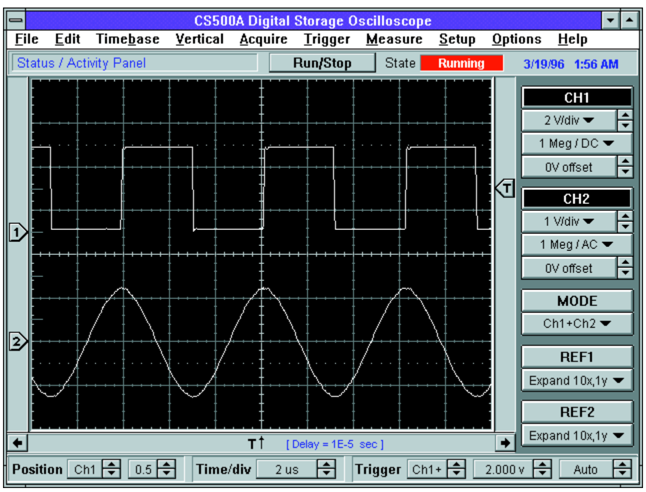
- ❏ radar signal analysis
- ❏ nuclear instrumentation
- ❏ linear accelerator event detection
- ❏ high-frequency spectrum analysis
- ❏ communication channel testing

Although most of these applications are typically customized using software drivers, you can also use a Virtual Oscilloscope interface such as the one found in National Instrument's LabVIEW to completely emulate a Digital Storage Oscilloscope (refer to Figure 1). Some companies produce their own proprietary interface (see Figure 2). DOS Drivers typically come in Basic, C, and Pascal. Windows drivers are usually in the form of a DLL (Dynamic Link Library), which is probably the most versatile driver type if you are running Windows 3.1, Windows 95, or Windows NT. The language in which the DLL was written does not usually matter as long as the function calls are well documented. You can use any language to create function calls to a DLL.



Courtesy of National Instruments

Figure 1. Screen shot of LabVIEW Digital Storage Oscilloscope GUI



Courtesy, Chase Scientific Company

Figure 2. Screen shot of custom Digital Storage Oscilloscope GUI

Some may argue that a data acquisition card is radically different than a DSO. In truth, they actually share the same basic subsystems. Data acquisition cards typically have more memory, fewer gain settings and fewer triggering functions; although some cards will have low impedance inputs – say, between 50 and 75 ohms. When using good Virtual Oscilloscope software, these differences are usually minimized. Most people never use 95% of the features on standalone DSOs.

While many of these applications are relatively new to the PC/104 markets, by using the appropriate PC/104 module carrier/adapter card, the data acquisition solutions designed on a PC/104 module can be installed across a majority of other platforms such as:

- ❏ ISA
- ❏ PCI
- ❏ CompactPCI
- ❏ VME
- ❏ VXI

This provides a backwards compatibility that is unprecedented. One of the few exceptions to this scenario is PCMCIA cards. However, the power/ cabling issues and extreme space constraints associated with these small cards limit their practicality for most data acquisition uses. Several companies are already looking into extremely thin (1.0" tall), lightweight, notebook-style cases that will satisfy the data acquisition requirements of the field engineers who want to use their notebooks as a controller as well as a computer. These enclosures could house up to five PC/104 cards using special, low profile connectors, as well as one I/O communication port such as a Parallel Port, PCMCIA, USB, or FireWire. While taller cases would obviously allow several layers of boards, the thin enclosure would fit easily into the same carrying bag as the notebook computer itself.

Taking advantage of the PC/104 size – unique opportunities

Clearly, the PC/104 form factor has yet to be exploited in the high-speed data acquisition market. Take a good look at the solutions involving a DSP and an A/D converter. You have to buy two ISA or PCI cards; taking up two slots to create this function is expensive and redundant. The DSP card should access the same RAM that the A/D utilizes.

Since both cards have their own RAM, the computer has to retrieve the data from the data acquisition card, then send the data through the bus again to get it over to the DSP card for processing. Of course, faster ways are available to get the data between cards, especially when using a PCI bus.

By using an ISA bus carrier card (or stacked PC/104 arrangement) with a PC/104 DSP card and a PC/104 data acquisition card, you'll achieve faster results than you would with two PCI cards. This solution assumes that the PC/104 cards either share memory space through a short, high-speed connector, or that they use a local memory controller built into the ISA bus carrier card.

Most PC/104 modules are designed with power-saving features, and high-speed PC/104 modules are no exception. This makes portable applications much easier to implement. For example, if you use a complete 386 computer module and a modem (from vendors like ZF Microsystems, Ampro or others) and a high-speed data acquisition board (from Chase Scientific among others), you can create a smart system to

High-speed data acquisition technologies...

perform remote, high-speed data capture and analysis. This system will also report its findings to you on a scheduled basis.

This technique can be a valuable remote diagnostic tool for analyzing problems in the field. Furthermore, it keeps your key development engineers working more at the factory and less in the field. Note the comparison of form factors versus function illustrated in Table 1.

As previously noted, you can fit at least five (5) PC/104 data acquisition modules in a slim (~ 1" thick), notebook-sized case. For the test equipment market, you could have a DSO card, a Logic Analyzer card, an Arbitrary Waveform Generator card, a Pattern Generator card, and a high-speed digital I/O card in a single enclosure. Your interface from this enclosure to your notebook can be a Parallel Port, Serial Port, USB, or a PCMCIA connector cable – whichever you decide. Although a complete package like this was not available at the time this article was written, check with the companies listed at the end of this article for the latest status. Many of these functions are expected to be available by the end of the year.

Instrument downsizing

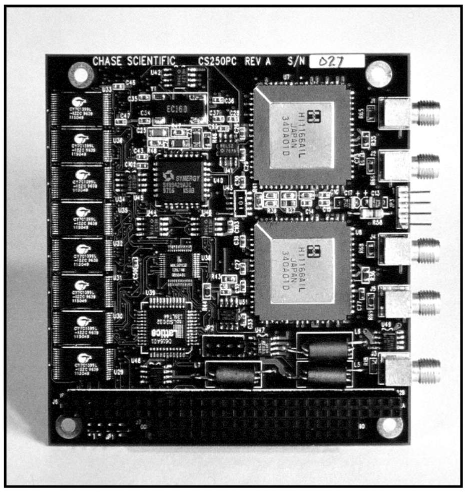
If you have visited a busy development lab recently, you probably found very little bench space. Most of it was likely filled with oversized pieces of equipment – and only a fraction of the available features were even being used. We are seeing a growing demand for smaller, lower power, portable instruments. Today's engineers are looking for products that do ***just what they want them to - no more***. In many cases, they are sharing a few pieces of expensive, general-purpose test equipment on carts, clearing benchtop space for more specialized tasks. Manufacturing lines are experiencing similar space constraints.

Another reason for the interest in stripped-down test equipment is planned obsolescence. After purchasing a new piece of equipment, it's typical to discover after a couple months that it's already obsolete. You know those annoying bugs and missing software features – *basic* features – that you have been complaining about? The fix always seems to turn up in the next generation product with a higher price tag. This pitfall can be avoided by buying small and inexpensive modular solutions that rely heavily on software for their advanced features. That way, you can download the latest software from the Internet or buy the exact hardware module upgrade that you need, as opposed to purchasing a completely new piece of equipment.

Smaller, lightweight, portable instruments are very attractive to the modern development environment. Because more and more of the new products developed are very software intensive, engineers are forced into doing more programming than ever before. The current preference is to perform this work in the main office whenever possible – the place where the main computer is located. However, the first choice would be to utilize small, portable data acquisition equipment with everything included in one or two small high performance packages. This would enable engineers to troubleshoot and repair problems right in the field, saving valuable time.

An advanced application of high-speed data acquisition that measures laser pulse shapes has been developed by SciTec of Princeton, New Jersey, for Night Vision Labs (NVESD) of Ft. Belvoir, Virginia. A 20 MHz, high-gain pin diode radiometer (along with customer electronics built by Sci Tec) produce the analog signal digitized by a 250 Megasamples/sec PC/104 A/D module. The captured samples are stored on a PCMCIA card on the PC/104 stack. SciTec reports the main factors in choosing this design included the availability of a PC/104 digitizer module that features a high sampling rate, relatively low-power and compactness. This product is battery powered and portable.

Another product available today from Saelig Company of Victor, New York, is used by major oil companies in North Sea oil drilling sites to measure echoes from rock formations.



Courtesy, Chase Scientific Company

Figure 3. Example of 250 MSamples/sec data acquisition module

Bridging the gap with PC/104-*Plus*

Whether or not the industry is ready, high-speed PC/104 data acquisition modules have the capability of bridging the gap between the lower-cost PC/104 module approach and the high-end PCI cards. The standard PCI computer boards,

Table 1. Relative Portability and Cost Between Form Factors

Function	PC/104	ISA/AT	ISA/PCI	Compact PCI
Relative Portability	High	Low	Low	Low
Relative Cost of Portability	Low	High	High	High

for example, could accommodate three PC/104 modules using a single carrier card. This carrier card approach is currently being used to interface PC/104 cards to ISA. The VXI/VME customers could probably use a little price relief as well.

Since the PC/104 boards are backwards compatible to ISA by means of an ISA-PC/104 carrier card, the ISA carrier cards can be used today to promote the PC/104 solutions. As an OEM migrates from an ISA bus platform using an ISA-PC/104 carrier card to the PC/104 platform, the same modules can be used in the new product. This also applies to a PCI carrier card or a CompactPCI carrier card. The benefits to the OEM can be considerable when using the same boards across different platforms. Since the OEM would be dealing with fewer critical components and buying greater volumes of the same board, material costs and overhead can be reduced. This migration path could be a powerful incentive for companies to move to PC/104 cards sooner rather than later.

Considering the PC/104-*Plus* standard recently released by the PC/104 Consortium, it looks as if high bus speeds will no longer be the sole dominion of high-end, expensive PCI cards. The PC/104-*Plus* specification adds an additional third connector, residing opposite of the current PC/104 connectors that supports the PCI bus. Although high-speed graphics and I/O devices such as networks were the primary driving forces behind this new standard, high-speed PC/104 data acquisition cards will benefit as well.

Among the potential hurdles facing the new PC/104-*Plus* standard are:

- ❏ the PCI bus interface requires more logic to implement than the AT bus
- ❏ the connector also takes a fair amount of space

The PCI connector real estate problem could be resolved simply by removing the PC/104 connectors and just using the PCI connector. However, this only works if you don't need the AT bus interface. Completely integrated PCI interface chips – while still only available from a limited number of vendors – are expected to shrink in size as well.

Terminology (SNR, THD, SINAD, SFDR, ENOB, Static Noise)

The following chart defines some commonly used terms when discussing high-speed data acquisition:

The way various industries view these parameters can provide some good insight into their significance as a function of application. A high SNR is crucial in Doppler Radar applications. Radar designers are willing to accept lower SFDR figures to obtain higher SNR. On the other hand, high SFDR is of prime importance in communication applications. For example, digital wireless applications can falsely detect spurs as channels. One way to achieve high SFDR at the expense of SNR is to restrict the full scale input range. Designers of data acquisition systems and automatic test systems are primarily interested in THD. Designers of medical systems and automatic test equipment are interested in high SINAD or ENOB.

Considerations when selecting a high-speed data acquisition card

First let's consider some A/D specifications, which is the place where most people get into trouble. Take for instance, sampling rates and input bandwidth. Much to the designer's frustration, sampling rate has no relationship to the input bandwidth. Texas Instrument's TLC5540 8-bit A/D has an input bandwidth of 75 MHz but a maximum sampling rate of 40 MHz. If we look at another part like the Philips TDA8703 8-bit A/D converter, we find an input bandwidth of 20 MHz and maximum sampling rate of 40 MHz. The maximum sampling rates are the same, but the input bandwidth of the TI part is 3.75 times higher. The input bandwidths are not at Nyquist as you might expect, but actually where the reconstructed signal from repetitive triggering drops 3 dB from its low frequency amplitude (usually at 95% of full scale).

You don't want your signal of interest to be anywhere near the BW of the A/D – even if you are undersampling – because the drop in amplitude at the –3dB point is caused by a multitude of problems and does not behave linearly like an analog filter. Typically, gross noise and distortion problems can occur at this point which are totally unpredictable. Beware, this is where marketers start to play games with the specifications. Many times the marketing material will list a number like 100 MHz, with no indication as to whether this is the bandwidth or the sampling rate.

Generally, you will get the highest fidelity signals at one-tenth of the input bandwidth or lower, with only minor degradation at one-fifth. When you are oversampling, it's good to keep your signal of interest below one-half of the Nyquist rate, which is one-fourth the sampling rate. It would be optimum to obtain the actual specs on the A/D chips used on

SNR	SNR (Signal-to-Noise Ratio) is the measure of the broadband noise introduced into the signal from the ADC (Analog-to-Digital converter) and the sampling process. SNR compares the magnitude of the input sinewave to the sum of all other frequencies, except those representing harmonics of the fundamental.
THD	Total Harmonic Distortion (THD) is the ratio of the power in the fundamental to the sum of the harmonics.
SINAD	SNR and distortion (SINAD) is the ratio of the power in the fundamental frequency to that in all others, including harmonics.
SFDR	Spurious-free dynamic range (SFDR) is the difference in magnitudes of the fundamental and the highest spur.
ENOB	Effective number of bits (ENOB) is another way of looking at the performance of an A/D converter and is given by the equation SINAD=(6.02N + 1.76)dB. The theoretical minimum A/D noise is caused by quantization error and is a direct result of the A/D's resolution. An 8-bit A/D converter, for example, can do no better than 50dB. Effective bits are calculated from a digital record taken from the A/D under test. In addition to the ideal quantization error of the device, other sources of error include all DC and AC nonlinearities, clock and aperture jitter, missing input codes, and noise. Noise on references and supplies also degrades effective bits performance.
Static Noise	Static Noise is the number of bits of instability in the output code with the analog input held at a constant DC level.

the data acquisition cards. The specification usually includes graphs of frequency input versus SINAD or ENOB and is a good tool for determining the quality of the signal you are going to receive at specific frequencies.

The performance will degrade a little further if you are acquiring signals with multifrequency content. These specs don't reflect the discrete time sampling effect; they are typically using time reconstruction. If you want the highest fidelity sampling and you are not sure of the specs, be sure to design with plenty of margin and watch out for cards that interleave two channels to achieve high sample rates. The input bandwidth doesn't change by using this technique.

Vertical resolution should be chosen to provide the minimum signal quality (SNR, etc.) required for the smallest input signal you expect to see for a given input range setting. If you expect to acquire an extremely wide range of signals amplitudes, you should look for a board with a wide range of software programmable gain settings. Simply choosing a 16-bit A/D converter card won't guarantee that you'll be able to eliminate noise problems at lower signal levels. It's better to have the proper gain to keep the signal amplitudes as high as possible across cables and PCBs.

On the list of considerations would be...

❏ number of channels and maximum number of samples you need to store
❏ methods of data transfers
❏ number of digital I/O ports
❏ number of DACs needed

Be sure to acquire enough memory for your application. Unless you planned an upgrade path, this could become a big problem: you might end up sending it back – or worse, buying a new card.

If you need to transfer data quickly between cards or between the card and system RAM without tying up the microprocessor, you will most likely want to be able to transfer using DMA access (direct memory access). The microprocessor can perform other tasks while the data is being transferred.

In addition, be sure to get plenty of digital I/O – especially if you don't have room for another card. This is particularly important for PC/104 applications. Digital I/O is inexpensive and merely takes up a few extra connector pins. Input and output clocks can be important, too. Remember to consider whether you need to synchronize the A/D (or D/A) with external circuits.

Since DACs are generally less expensive than A/Ds, obtain a few extra 12-bit analog outputs. Later, you may want to control a power supply or something else you have overlooked. While DACs can be very handy, the specifications as stated by the board manufacturer can be lacking (in ways that are similar to the A/Ds), so try to get the actual manufacturer's specifications if your application is sensitive to SFDR.

Power supplies also play an important role. While most companies have already moved to 5V only cards, some of the higher frequency cards may still require ±12V or –5V.

Entering a Growing Market

As with the ISA and the growing PCI markets, using a PC for data acquisition/DSO required a platform with a large enough installed base to ensure a market. In fact, the PC industry had to wait until 1989 when the first AT based DSO board was introduced to the market. Since then, this market has grown to over $20 million (refer to Table 2).

At this juncture – five years after PC/104 became an official standard – will history repeat itself? Considering the wide spectrum of support and products (CPU modules, peripherals, baseboards, enclosures, driver software and GUIs), designing an advanced high-speed data acquisition system from readily available building blocks has never been easier.

Now that high-speed PC/104 data acquisition cards are finally becoming available, the market is positioned for explosive growth. Applications range from laboratory test equipment to embedded control systems for ultrasonic testing. Not only are unique opportunities emerging from PC/104's compact size, but with the appropriate bridge technology, these high-speed acquisition modules can be used across multiple platforms and industries.

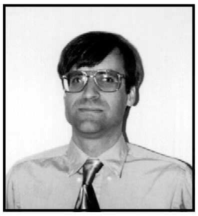
Although the technology to support most PC/104 data acquisition solutions has been available for a few years, the designs are just now reaching the marketplace. The current operating systems available for embedded markets are fully capable of supporting this effort. Even the CE operating system by Microsoft is fueling this market by allowing integrators to run Windows applications with significantly less memory.

At this point, it would be difficult for anyone to miss the PC/104 signs along the path that leads to the future. OEMs and system builders would do well to consider the new,

Table 2. Comparison of Market Size for High-speed (>1millisecond/sec) Data

Data Acquisition Form Factor	Installation	Architecture	Relative Size	Size of Market 1997
PC/104	Embedded, compact enclosures, busless	Open	Small	<$100,000
AT-ISA/PCI	Embedded, bus, backplane required	Open	Medium	$20-30 Million
Standalone/Rack Mount	Requires considerable floor/rack space	Closed	Very Large	~ $1 Billion

emerging PC/104 high-speed data acquisition technology for their projects. Doing so will enable them to harness the most desirable combination of compact form factor, low-power requirements, performance and inter-bus flexibility. Ω



Frank Chase has served as President and Principal Engineer for Chase Scientific Company since 1987. He has 17 years experience designing high-frequency analog and digital circuits for a number of Silicon Valley companies. Frank received his EECS bachelor's degree in 1981 from the University of California, Berkeley.

Don Krenn recently joined Chase Scientific as Vice President of Sales and Marketing. Prior to Chase Scientific, he spent three years at Emulation Technology as Manager of the Development Tools Division. Donald holds a BSEE from the University of Hartford in Connecticut.

For questions about this article or more information on PC/104 technology, feel free to contact:

Don Krenn
Chase Scientific Company
7960-B Soquel Drive, Suite 191
Aptos, California 95003
Tel: 408-464-2584, Ext. 503
Fax: 408-479-8572
Email: dkrenn@chase2000.com

Manufacturers and Suppliers of PC/104 High-Speed Data Acquisition Modules

Chase Scientific Company
7960-B Soquel Drive, Suite 191
Aptos, CA 95003
Tel: 408-464-2584
Fax: 408-479-8572
Email: sales@chase2000.com

Diamond Systems Corporation
450 San Antonio Road
Palo Alto, CA 94306
Tel: 650-813-1100 or 1-800-367-2104
Fax: 650-813-1130
Email: techinfo@diamondsys.com

Saelig Company
1193 Moseley Road
Victor, NY 14564
Tel: 716-425-3753
Fax: 716-425-3753
Email: saelig@aol.com

Other PC/104 manufacturers mentioned in this article...

Ampro Computers, Inc.
4757 Hellyer Avenue
San Jose, CA 95150
Tel: 408-522-2100 or 1-800-966-5200
Fax: 408-720-1305
Email: info@ampro.com

ZF MicroSystems, Inc.
1052 Elwell Court
Palo Alto, CA 94303
Tel: 650-965-3800 or 1-800-683-5943
Fax: 650-965-4050
Email: dfeldman@zfmicro.com

