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Setting a Trap For Mask-Programmed ROM Errors

by Tom Cheek and Guenther Wimmer

In the past couple of years, microprocessors have created far-reaching changes in electronics. In our industry, they are simplifying and minimizing hardware elements in an ever-widening range of products and increasing capabilities in the bargain. At Tektronix, we are seeing microprocessors control everything from plug-in devices to graphic computing systems.

In designing products that include a lot of permanently programmed memory (ROM), we are faced with the fact that mistakes will occur—just as they have always occurred with conventional hardware. The difference between mistakes associated with ROM and conventional hardware is: (1) ROM-based products usually have many more features than previous products and thus greater opportunity for errors; (2) the methods for correcting ROM errors are more varied than for conventional hardware problems.

Planning for errors should be an integral part of the design process. The assumption of no errors is likely to make the inevitable error correction costly, difficult to administer, and, if not done smoothly, can result in alienation of customers.

To recognize and plan for the possibility of mistakes is the start of a solution. Because no one plans mistakes and, therefore, cannot admit that any expense to correct them has an economic justification, we lack an objective basis for evaluating the possible solutions; history and probability must be the guide.

Several possible solutions to the problem of bad ROMs, applied to an 8-bit microprocessor system, have been investigated. These solutions require the capability for installing a patch device in the instrument to correct firmware errors. These solutions have been evaluated in the following respects.

1. Adding the patch capability should cause a minimum increase in manufacturing cost.

2. The solution should allow a quick, selective response to firmware problems.

3. The patch should be easily installed in manufacturing at a minimum cost until new ROMs can be made available.

4. The patch should be easily installed in the field (hopefully by the customer) without tools or plugging in chips. This would save the cost of a (≈) $100 service call.

5. The solution should allow firmware with critical timing constraints to be fixed (i.e., not add any execution time).

Rejected Solutions

One considered solution would have the system program memory leave a flag bit to identify ROM error locations assigned on a per-byte basis. The flag bits from a patch PROM would be loaded into a dedicated RAM at system initialization. An error flag detected during a memory access would force a processor interrupt. The interrupt service routine would then direct to a byte or block code substitution. This method was discarded because it burdens the design with an additional memory system and has limited application for fixing time-critical firmware due to the time for servicing the interrupt.

Another considered solution would use a conventional 16-input, 8-output, 48-product term FPLA (field programmable logic array), such as the 82S100, to monitor the processor address bus. As shown in figure 1, the FPLA product is connected through a tri-state buffer to the processor data bus and to an 8-input NAND gate connected as an active low-input OR gate. The FPLA product is programmed with the complement of the new code. The FPLA is programmed to give all "1s" at the output when the FPLA inputs are not valid. The presence of any "0" at the FPLA output indicates an "Input Valid" state which is used to disable system ROM. Simultaneously, the FPLA product is placed on the processor data bus through the tri-state buffer. While this method has the advantage that it can implement either single- or multiple-byte patches (one product term is consumed per byte) with an FPLA and two SSI (small-scale integration) elements, restricting the patch codes prohibits a byte substitution containing FF_{16}. Therefore, this "solution" was also rejected.

A Realistic Solution

A realistic solution to firmware correction can be realized by using both an FPLA and a PROM. The FPLA inputs monitor the address bus, while the outputs drive the high-order address inputs of the PROM. Low-order address inputs to the PROM are derived from the processor address bus. Firmware patches occur in blocks of 4, 8, 16, etc. The size is determined at the time of implementation. In addition, the most-significant bit of the FPLA is dedicated as an "Input Valid" flag to enable the patch PROM and disable system ROM. Should the patch to be inserted in place of the erroneous code exceed the space of the ROM code, a second ROM (or multiplexers for the high-order address inputs of the existing PROM) must be added as shown in figure 2. The advantages of this method are virtual firmware transparency and the ability to service block-oriented and byte-oriented code replacement. A drawback is that to service even a minimal code error, both an FPLA and a PROM are required.

A Nearly-Ideal Solution

A nearly-ideal solution to the problem of servicing errors in firmware code could be implemented with a modified 82S100-type FPLA, which is not yet available. The proposed mod adds a ninth product term. This ninth output is not programmable; it does, however, indicate a recognized input address status which enables the FPLA outputs and may be used to disable system ROM. Using this method, firmware code errors may be serviced with just one component in an 8-bit machine. The advantage of firmware transparency is retained, with no restriction on block or byte patches.

Large blocks of code can be overlaid by having the FPLA instruct the microprocessor to jump to an optional patch PROM by substituting the error code with three bytes, the jump OP code, and the high- and low-order address bytes.

Conclusion

The third and fourth solutions are the most practical for fixing firmware with critical time constraints. They are both virtually transparent to firmware code. The exception of possibly adding two jumps to the erroneous codes must be considered in the initial design of any time-critical code. Vendors have shown an interest in supplying the modified 82S100 FPLA, mentioned in the fourth solution, so it may soon be a reality. In the meantime, the third solution is being implemented as a small board containing the FPLA, PROMs, and the support circuitry which may be plugged in without tools from outside the instrument (like a 4051 ROM pack).

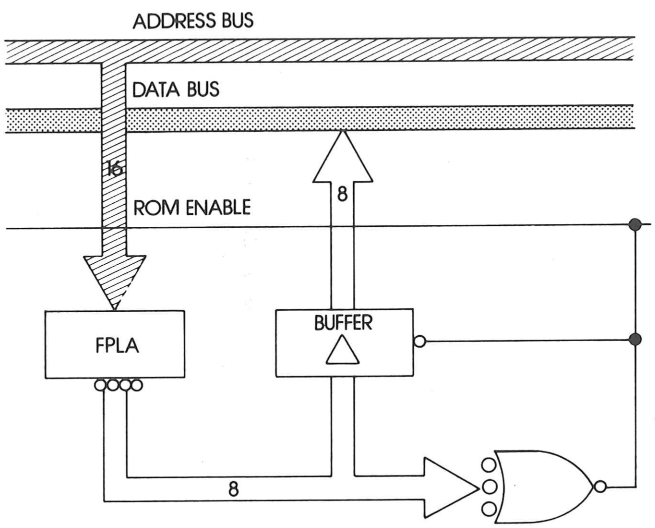

Figure 1. An FPLA used to monitor the microprocessor address bus.

Anyone who is interested in more information on this subject should call Guenther (2676 Wilsonville) or Tom (2631 Wilsonville).

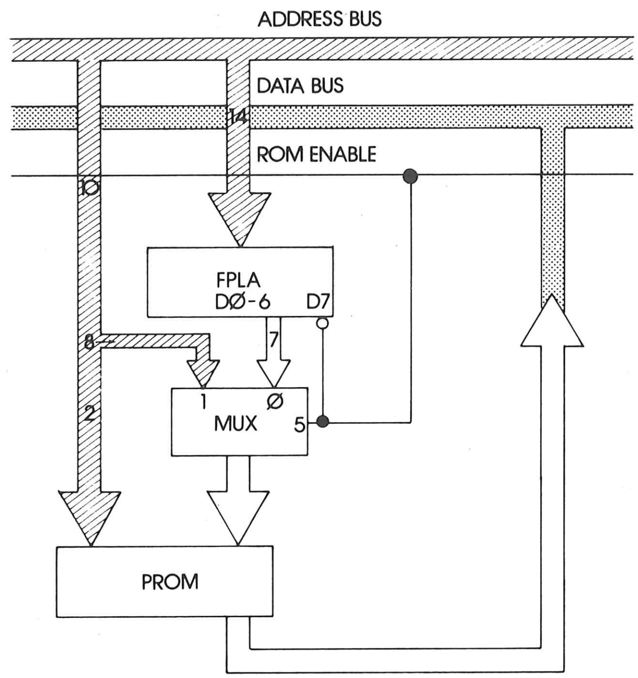

Figure 2. A successful method for correcting firmware errors using an FPLA and a PROM.

Plotting Programs For The Tek 31

Tony Tunder, in Hybrid Circuit Engineering, has developed four applications programs for the Tek 31 desk-top calculator. Tony developed the programs over the last year to analyze characteristic-life data for NiCr Thin Film Networks. The programs are useful in any application where the data is easier to understand in a graphical form.

Tony used a 4661 Digital Plotter to output the diagrams we've used as examples.

SUPERFAST HISTOGRAM. This is the largest of the four programs (it's about 4000 lines long). SUPERFAST HISTOGRAM plots histograms (bar charts) with alphanumerics (see figure 1). A histogram is a graph that represents frequency distribution with rectangles rather than with individual data points. The width of each rectangle represents the class interval; the height of each rectangle represents the frequency that corresponds to each class interval.

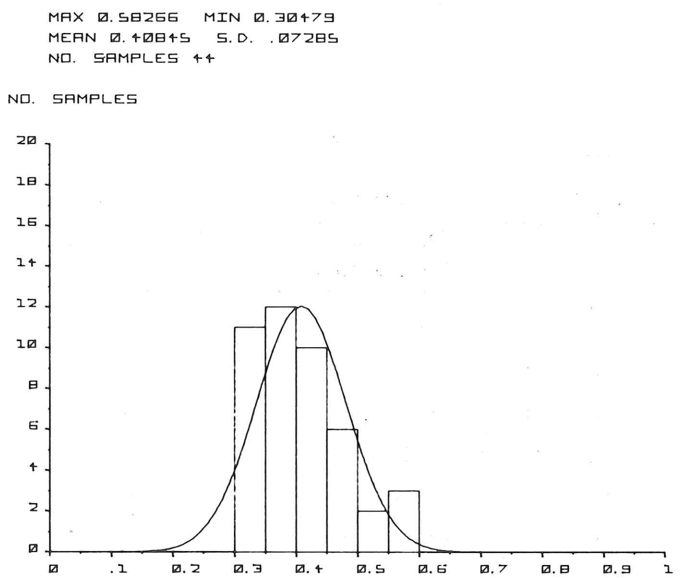

Figure 1. Superfast Histogram Plot.

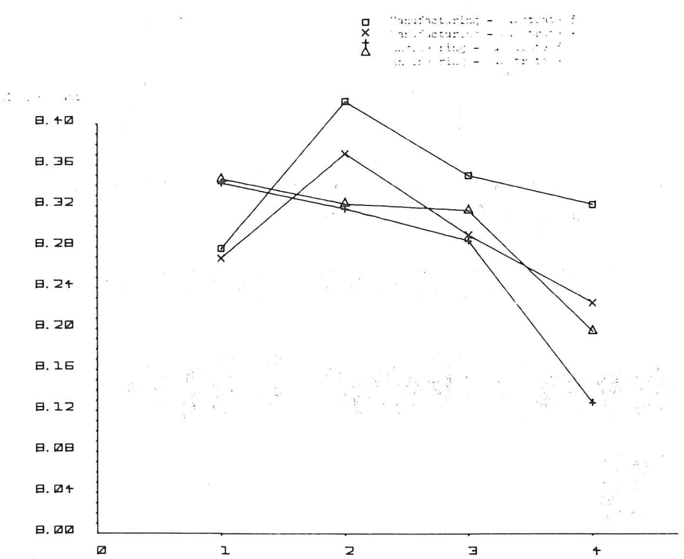

Figure 2. Discrete Data Plot: Multiple.

DISCRETE DATA PLOT. This program plots individual data points. When you're running the program, you have a couple of options. You can either make multiple plots on the same graph (see figure 2) or you can make a single plot and include variance bars to show the range of the data (see figure 3). This program also uses alphanumerics. The program is about 4000 lines long.

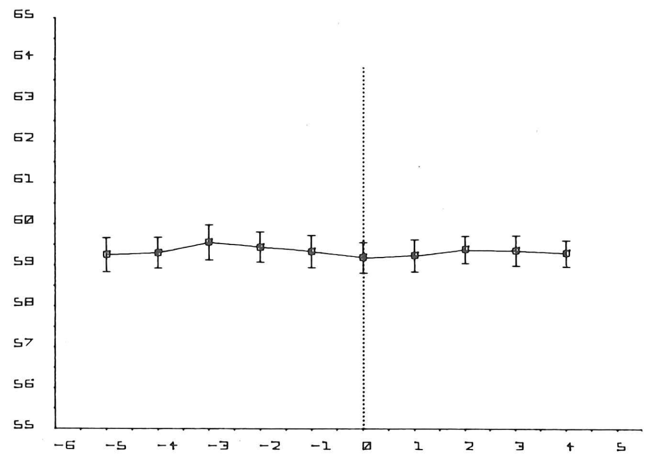

Figure 3. Discrete Data Plot: Single.

PREPARED GRAPH PAPER is the third program. If you're planning to plot on prepared (prelined) graph paper, this is the program to use (see figure 4). Since alphanumerics are too hard to coordinate with the fine spacing of prelined graph paper, Tony eliminated alphanumerics from this program. The program is only about 2000 lines long, so you have more room for data.

Figure 4. Prepare Graph Paper Plot.

3-D PLOT is the fourth program. Use this program if you want to graphically represent a surface (figure 5). It's a convenient way to check on the uniformity of the surface of a solid. This program has no alphanumeric capability, so it requires only 500 lines.

If you have any questions, or if you would like a copy of any of the programs, give Tony Tunder a call at extension 5823.

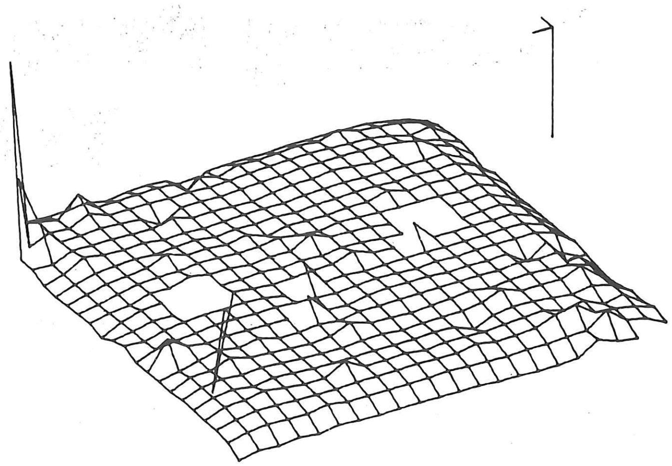

Figure 5. 3-D Plot.

A Transversal Filter For TV Products

Using surface acoustic wave (SAW) technology, Tek Labs' Instrument Research group has produced a new transversal filter to be used in a precision demodulator being developed by the Communications Division.

Every filter shapes the signal transmitted through it. Most filters use resonance to shape the transmitted signal. A transversal filter, through, uses time delay to correctly shape the signal.

Think of the transversal filter as a transmission line with many taps. The signal is injected at a set of input taps spaced along the line. The output signal is the sum of the contributions of a second set of taps. The output taps are spaced apart by some fraction of an incoming signal's wavelength. Because of their different wavelengths, some frequencies in the transmitted signal will cancel and others will be reinforced. The result is the correctly shaped bandpass.

The transversal filter developed by Instruments Research is radically different from other filters on the market because

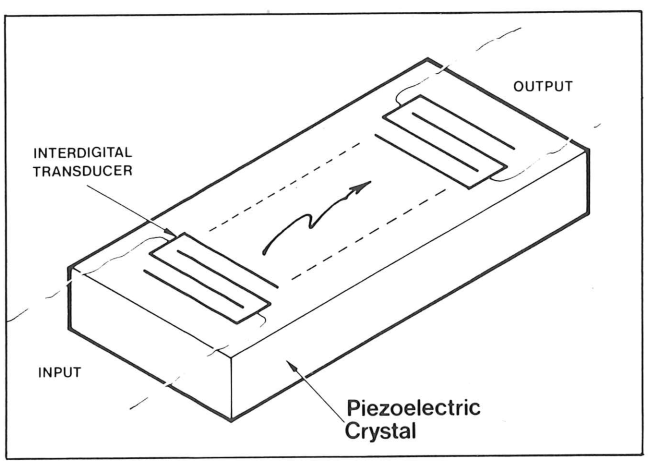

Figure 1. A Surface acoustic wave delay line.

it was developed from surface acoustic wave technology rather than electromagnetic technology. Surface acoustic waves are mechanical waves that roll across the surface of a solid.

Electromagnetic waves can be converted into surface acoustic waves with a piezoelectric transducer (see figure 1). In principle, the SAW transversal filter operates like electromagnetic transversal filters. Then why use SAW technology?

First, it's more convenient to filter high frequencies with a SAW device than with an electromagnetic device. The reason is that transversal filters require delay. The electromagnetic wavelength of a 300 MHz signal is one meter. The surface acoustic wavelength is about 10 microns. That fits many wavelengths into a small space. Thus, SAW technology allows the designer to add many more taps than can be added to the equivalent electromagnetic transversal filter. More taps mean more resolution in shaping the transmitted signal. The designer can independently control bandpass shape and group envelope delay—giving him a lot of flexibility.

A second advantage of SAW technology is that SAW filters are easier to make. Manufacturing requires only a one-mask process, metal-on-insulator. The single-step masking process makes it easy to control delay flatness, symmetry of the Nyquist slope (which we will look at later), and the bandpass shape. Most attractive is that the SAW device requires no calibration or maintenance. An electromagnetic filter, however, has to be calibrated periodically.

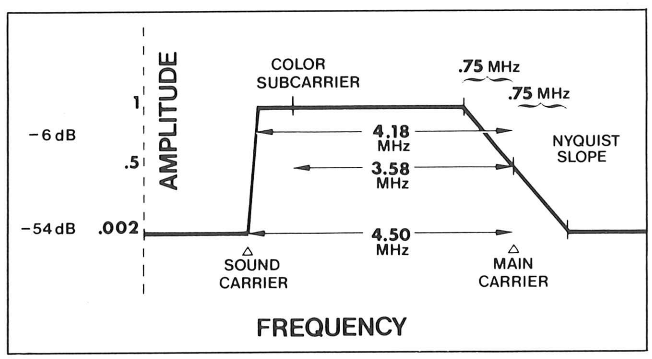

Figure 2. The SAW transversal filter bandpass curve.

Everything isn't roses for the SAW filter, however. There's one big problem: the overall filter loss is very high. In the SAW filter that TV Products is using in its precision demodulator, the loss is about 30 dB. This is a 97% loss of the input signal voltage.

In March of 1976, TV Products showed a prototype of the precision demodulator that used the SAW filter. The purpose of the precision demod is to evaluate TV transmitter output.

The SAW filter in the precision demod shapes the vestigial sideband as shown in the bandpass curve in figure 2. The figure points out the main carrier, sound carrier, color subcarrier, and the Nyquist slope. The purpose of the Nyquist slope is to weight the sidebands so that they will add to reproduce the original flat bandpass characteristics. The purpose of the filter in the demod is to produce the Nyquist slope and to suppress the sound carrier without adversely affecting the color subcarrier. Evaluation of the TV signal requires 600 kHz more information beyond the color subcarrier (which is 3.58 MHz from the main carrier). So, the filter is designed to roll off the bandpass at around 4.18 MHz. With the SAW filter, the roll-off is very sharp.

If you have any questions on the SAW filter, give Gene Chao a call at extension 7435; if you have any questions about TV Products' use of the filter in their precision demodulator, give Steve Roth a call at extension 7457.

NEW DC TO 50 MHz CURRENT PROBE/AMPLIFIER

The new Tektronix P6302/AM 503 Current Probe/Amplifier (figure 1) can directly read current levels up to 20 A (dc plus peak ac) at frequencies ranging from dc to 50 MHz. Peak readings up to 50 A are also possible, provided the current-time product does not exceed 100 amp-microseconds. Dc overloading and consequent probe saturation turns on a red warning light to indicate calibrated limits have been exceeded.

The AM 503 plugs into any TEKTRONIX TM 500 Series mainframe. The output can be connected directly to any 50-ohm scope input or through a 50-ohm termination to a high-impedance input (a 50-ohm termination is included in the probe/amp package).

The probe might be especially valuable in looking at current in solid state circuits because of it's ability to display both high- and low-frequency components of the current waveform. It should also find extensive use in monitoring the fast-switching action of SCR's, power supply current regulation, and in looking at the low currents encountered in biophysical and medical research.

For more printed material on the P6302/AM 503, call Ken Arthur at extension 6974.

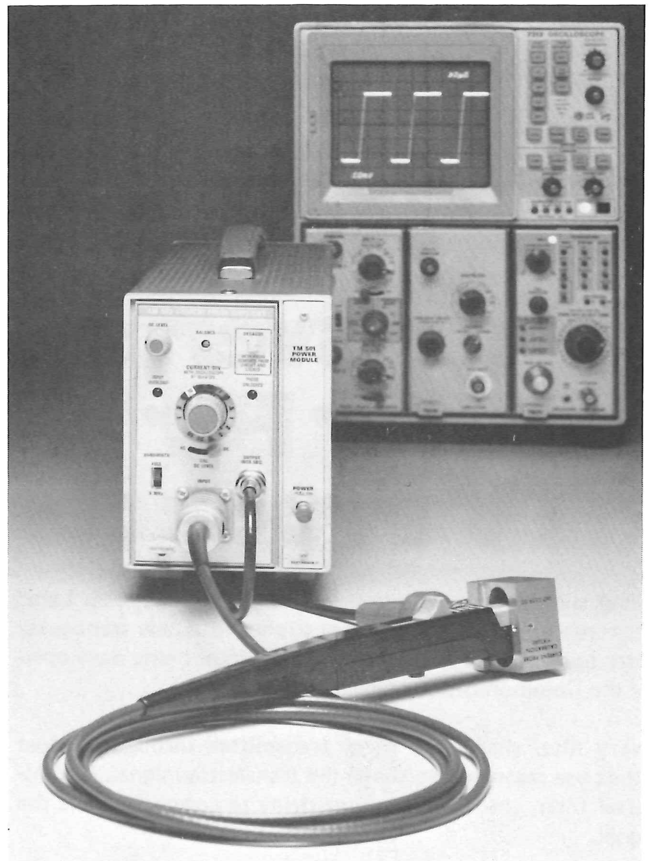

Figure 1. P6302/AM 503 Current Probe/Amplifier.

SURVIVAL GUIDE UPDATES

WHAT?, WHO?

That's right! Updated and new pages for the new engineer's "survival guide" have been mailed to those persons that are known to have a book. For the uninitiated, the proper name for the survival guide is "Who, What, When, Where, How—An Engineering Sourcebook for Tektronix." The survival guide tells an engineer who can help him do his job, and what resources are available to him within Tek.

If you did not receive your updates, or need a copy of the book, fill out the coupon below or call Al Carpenter on Ext. 5468.

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If any of these calls for papers interest you, give us a call (Technical Information, ext. 5468 or ext. 6071). We will give you all the details you need (length and format of the paper, where to send it, etc.). We can also help you with the writing, illustrations, typing, and mailing.

CALL FOR PAPERS

The British publication, **Noise Control, Vibration and Insulation,** is looking for articles for its May 1977 issue on the topic of signal processing of vibration, shock and noise. If you have an article idea you'd like to pursue, let us know as soon as possible. Call extension 6071. We'll contact the publisher for you.

—The IEEE MTT-S is sponsoring the 1977 International Microwave Symposium (June 21 through 23) in San Diego, California. Papers are solicited describing original work on microwave techniques, devices, systems, and applications. The paper can be theoretical, technological, or application oriented. An abstract and preliminary paper, which explain their contribution, originality, and relative importance must be received by the papers chairman by January 15.

—The IEEE Group on Electron Devices is sponsoring the 1977 Device Research Conference (June 27 through 29) at Cornell University in Ithaca, New York. They are calling for papers on electron device research, especially in new or rapidly developing fields. The deadline for paper submission is March 1, 1977. If you have a topic in mind and are not sure if it is applicable, call Technical Information on ext. 6071 or 5468.

—The Institute of Electrical and Electronics Engineers, Inc. will publish a special issue of **IEEE Transactions on Microwave Theory and Techniques.** Papers are solicited describing original work concerned with high levels of microwave power, and may deal with theory or application. The manuscript must be received by the editor by May 15, 1977.

SOFTWARE MAINTENANCE, A NEWSLETTER

In November, Signal Processing Systems published the first issue of **Software Maintenance Newsletter.** Intended for Tektronix customers who have SPS software, the newsletter is also available to Tektronix people. The newsletter will provide a list of software bugs (and how to fix them), a list of corrections for the manuals, and announcements of new software.

If you are using a Tek BASIC software package, you might want to take a look at a sample copy. Call Dale Aufrecht at extension 5706.

IN PRINT

"Howard Vollum, Bill Peek, and Wim Velsink of Tektronix Speak on the Future of the Scope" is the title of an article in the November 22, 1976 issue of Electronic Design magazine. They discuss uses for the oscilloscope in tomorrow's world of inexpensive integrated circuits and microprocessor-based digital circuitry. Howard, Bill, and Wim point out that technological advances in semiconductors, crt's, a/d converters, etc. allow performance improvements which enable the scope to keep pace with the electronics industry as a whole. They conclude that although the general configuration, operating parameters, and variety of functions will change as needs require, they believe that the scope will continue to be a basic diagnostic tool.

If you want a copy of this article, call the library on ext. 5388. The article is in Vol. 24, No. 24, pages 68-73.

Many Tektronix instruments are discussed in several articles in this same issue of Electronic Design (e.g., the use of microprocessors in the DF1 Display Formatter). Other manufacturers' instruments are also discussed and compared.

IN PRINT

In November, **Computer Design** published an article written by Tom Cheek and Peter Cook. The title of the article is "Impact of LSI on Terminal Architecture". Peter Cook is the IDS engineering manager. Tom Cheek is a senior engineer in IDP. If you would like a copy of the article, call the library at extension 5388. The article is in Vol. 15, No. 11, pages 103 through 107.

SPECIAL DESIGN FILE

Here are some more drawing packages which are available for the asking. These are designs which were built by various groups for their own use; they might be adaptable for other areas. If you would like a copy of any of these drawing packages, call Burgess at ext. 6071. Also, send drawing packages and brief descriptions of any special designs that you would like to share to Special Design File, 50-462.

File No. 0019
10 kHz to 3 MHz SAMPLE RATE CCD DRIVER

1. Four phase push or drop clock option.
2. Load signal during phase 1 or phase 1 and 2.
3. Gated synchronous stop-phase clock option.
4. Dual output amplifiers.
5. Clock input compatible with 191 Signal Generator.
6. Fat zero control (Ø to −20 volts), with signal input option.
7. Output diffusion—output jack (shielded).
8. Substrate bias control (Ø to −20 volts).
9. Gate drivers variable gain (5 to 15 volts) and bias (+5 to −20 volts) with rise and fall time ≈12 ns at 25 pF, outputs all diode clamped to +5 and −20 V to protect device.
10. Dual-wired sockets 40-pin DIP and 24-pin DIP.
11. Sample and hold drive pulses generated ≈5 ns at 3 volts.
12. Supply +15, +5, −50 volts.
13. Floating Gate Bias control with phase coupling.

—Gary Spence

File No. 0020
7000 Series Universal Power Plug-in

1. Fixed or variable +50, +15, −15, −50 at >200 mA.
2. Fixed +5 V at >500 mA.
3. Variable programmable bias voltages at <2 mA.
4. Voltage warning lamp (if output voltage goes out of regulation).
5. Current overload warning lamp.

—Gary Spence

File No. 0021
512 X 512 D-to-A Converter Display with Readout

1. 512 X 512 full parallel display of an X-Y data point.
2. X and Y axis zero position control.
3. Device OFF-ON switch.
4. Z-axis brightness adjust.
5. Vertical address number readout.
6. Horizontal address number readout.
7. Built to work with 7000 series scopes with AUX Y axis in horizontal compartment.

—Gary Spence

File No. 0022
10 μA/volt Current Amplifier

1. 10 microampere/volt sensitivity.
2. 2 mV p-p noise and short term drift.
3. < 1 μs rise and fall time.
4. Input impedence 2 kΩ at 5 mV and 200 Ω at 50 mV offset.
5. Supply ±5 V at 20 mA.

—Gary Spence

File No. 0023
80 MHz Variable Duty Cycle Square Wave TTL Clock Drive

1. Variable duty cycle square wave (25% to 75% —ON).
2. Gated clock option.
3. Requires a sign wave 50 Ω signal generator input (TEK 191).
4. Output rise and fall 4 ns into 50 Ω to 100 Ω at 2 volts.
5. Supply +5 volts at 100 mA.

—Gary Spence

ORGANIZATION CHARTS

In this issue of Engineering News, we are including organization charts for HCE (Hybrid Circuits Engineering) and MCE (Monolithic Circuits Engineering). These charts are a bit unusual in that they show functions and capabilities as well as structure. We intend to print more organization charts in future issues.

—ed.

TECHNICAL INFORMATION DEPARTMENT:

WHAT WE DO

We are a service department. Our main function is to help Tektronix engineers communicate with other technical people, by providing the graphics and typing for

- **slide shows**
- **papers** for conferences or journals
- **articles** for trade magazines

We also publish **Engineering News.** If you have an announcement that should reach Tek engineers, or a new development that other people in the company should know about, this is the place for the publicity.

If you have a project we can help you with, let us know. Call extension 5674, 5468, 6071, or 6601. Or come by 50-462. We're right across the hall from the central elevator on the fourth floor of building 50.

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MANAGER

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LESLIE MEHARRY
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- PROCESS SPECS
- TEST SPECS
- DRAFTING
- IC DESIGN CATALOG

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- SHF III
- HI VOLTAGE
- SPECIAL PROCESSING
- CCD
- J—FET
- SCHOTTKY DIODE

DISCRETE DEVICE DEVELOPMENT

N—P—N
- POWER
- LOW NOISE
- HIGH FREQ

P—N—P
- COMPLEMENTS OF ABOVE

GaAs FET

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GEORGE WILSON, ext. 7633

BIPOLAR DESIGN

- STANDARD PROCESS ≈800 MHz
- SHF II ≈2.5 GHz
- SHF III ≈6.5 GHz
- I^2 L
- A/D
- J—FET

MOS

- N—CHANNEL
- C—MOS
- P—CHANNEL

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—Multi-Chip Hybrids
—μ Wave Circuits
Hybrid Layout

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Thin Film Processing
—IC Metalization
—Film Material Consultation
—Scanning Electron Microscope and Other Testing

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IC's
Discretes
Package Development
Micro Assembly

TRIM & TEST

Dick Westlake, ext. 7266

Component Test
Component Trim (Laser)
Systems Development
Systems Support
Prototype Support

SUPPORT

Jack Hurt, ext. 6545

Analytical Support
—Mechanical
—Thermal
Thermal Testing and Characterization
CAD Development