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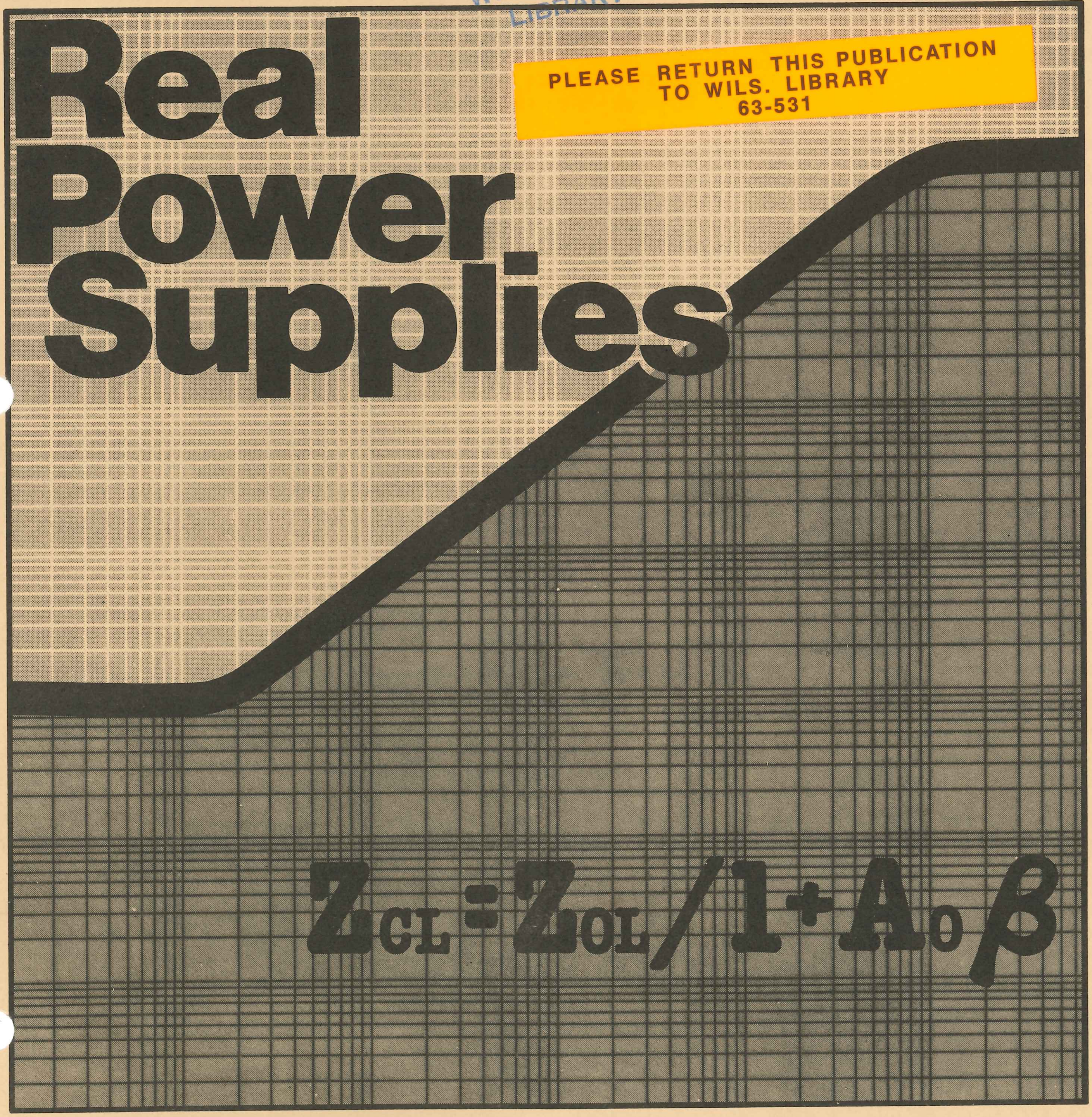
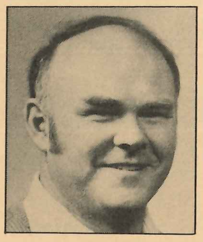


REAL POWER SUPPLIES



Laudie Doubrava, Signal Processing Systems Engineering, ext. 1119 (Walker Road).

This is the second in a series of articles about bypassing and decoupling. The first article, "From Paper to Circuit Board: Bypassing," appeared in the April 1978 **Engineering News.** For a copy, call T&M Publicity on ext. 6792.

The previous article on bypassing assumed an ideal voltage source represented the power supply in the bypassing-circuit examples. To examine bypassing and decoupling further, we need to examine real power supply characteristics.

OUTPUT IMPEDANCE

Power supplies are designed to have a low output impedance to ensure a constant voltage output even with load current changes.

Unfortunately, real power supplies aren't low output-impedance sources at all frequencies. At dc and low frequencies (up to around 10kHz), they are nearly ideal voltage sources, but at higher frequencies output impedance rises. The circuit designer can use bypassing to decrease the output impedance at high frequencies, but the price of bypassing may be ringing at the power supply output or even oscillation.

ELECTRONICALLY-REGULATED POWER SUPPLIES

Electronically-regulated power supplies use gain to decrease output impedance: the voltage regulator senses the output voltage, compares it with a reference voltage and generates a correction at the output. See figure 1.

This feedback loop compensates for the voltage drop across the regulator's output resistance, R_O, produced by the load current. If the power supply has zero output impedance, load-current changes do not affect output voltage and feedback isn't required.

SYMBOL TABLE

A_O	Open-loop gain of the feedback amplifier.
$A_O\beta$	Loop gain, the product of open-loop gain and feedback gain.
β	Feedback network gain.
C_{BY}	Bypass capacitance.
ΔI	A change in current.
$\frac{dI}{dT}$	Rate of change of current (amps-per-second).
L_{PS}	Effective inductance of a power supply.
R_D	Damping resistance.
R_L	Load resistance.
R_O	Open-loop output resistance. Output resistance of a regulator without feedback.
Δt	A change in time.
V_O	Power supply output voltage.
V_P	Peak transient voltage.
X_L	Reactive impedance of an inductor. $X_L=2\pi fL$.
Z_{CL}	Closed-loop output impedance.
Z_{OL}	The output impedance obtained with the feedback loop open. This impedance is equal to the load impedance in parallel with the open-loop output resistance, R_O, of the regulator.

For a series-pass regulator, a typical open-loop output impedance (without feedback) is 50 ohms. With feedback, closed-loop output impedance may be less than 10 milliohms at low frequencies. However, as the feedback amplifer s gain decreases with frequency, the electronically-lowered output impedance increases. See figure 2.

The output impedance increases until the gain drops to 1, at which point the output impedance reaches its open-loop value, Z_{OL} (50 ohms in this example). Above this frequency, there is no gain to correct the output voltage for load current changes.

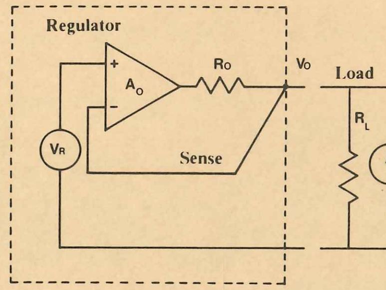


Figure 1. In this simplified voltage regulator model, the feedback loop compensates for internal voltage drops across R_O due to current load. The regulator senses the output voltage V_O, compares it to the reference and generates a correction at the output.

A regulator's closed-loop output impedance, Z_{CL}, is related to its open-loop output impedance, Z_{OL}, and its loop-gain characteristic $A_O\beta$, by the equation

$$Z_{CL} = \frac{Z_{OL}}{1+A_O\beta}$$

FEEDBACK REGULATOR EXAMPLE

Let's look at an example of the effects of gain on closed-loop output impedance. In this example, R_L is 12.5 ohms, R_O is 50 ohms, and A_O is 5000 at dc with a single pole rolloff at 200Hz (a 1 MHz gain-bandwidth product) for the amplifier. See figure 3. Then, open-loop output impedance Z_{OL} is

$$Z_{OL} = R_L R_O = \frac{R_L R_O}{R_L + R_O} = 10 \text{ ohms}$$

and the gain of the feedback network, β, is the gain of a simple voltage divider.

$$\beta = \frac{R_L}{R_L + R_O} = \frac{12.5}{12.5+50} = 0.2$$

Therefore, the closed-loop output impedance Z_{CL} is

$$Z_{CL} = \frac{\left(\frac{R_L R_O}{R_L + R_O}\right)}{1 + \left(\frac{A_O R_L}{R_L + R_O}\right)}$$

For a loop gain much larger than 1, the closed-loop output impedance simplifies to

$$Z_{CL} = \frac{R_L R_O}{A_O R_L} = \frac{R_O}{A_O}$$

For loop gains greater than 1, ($A_O\beta > 1$) the closed-loop output impedance is inversely proportional to amplifier gain. For loop gain less than 1, ($A_O\beta < 1$) the closed-loop output impedance equals the open-loop output impedance. At dc and low frequencies, the output impedance is 10 milliohms. Above 200Hz, the closed-loop output impedance increases with frequency at the same rate as gain decreases with frequency. In the example above, gain decreases at a one-pole (unity slope) rate and causes output impedance to increase at unity slope. In other words, the output impedance has the characteristics of an inductor: impedance increases directly with frequency.

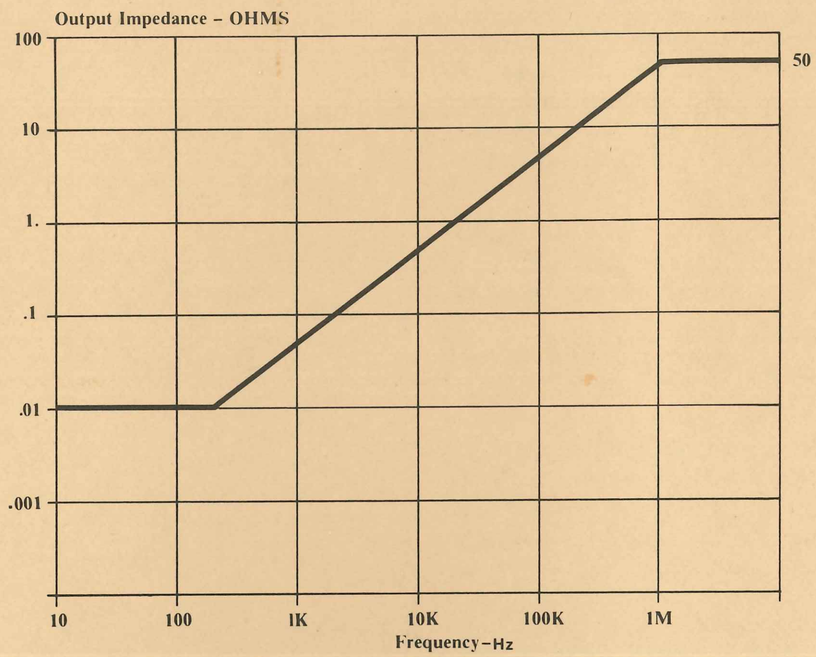


Figure 2. For a typical electronic voltage regulator, the output at low frequencies is 10 milliohms or less, but increases to 50 ohms or more at high frequencies.

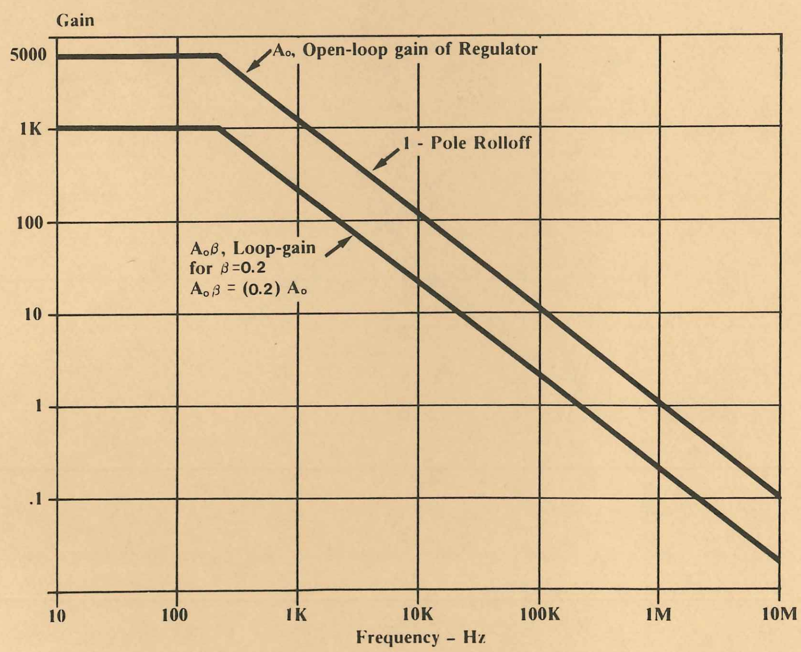


Figure 3. This graph shows the gain characteristics of a typical voltage regulator's amplifier. The gain decrease at higher frequencies causes the rise in power supply output impedance.

The closed-loop output impedance in this example is inductive over the frequency range 200Hz to 200kHz. This inductive component of output impedance isn't beneficial or desirable in a power supply.

INDUCTIVE CHARACTISTICS

Although produced by feedback, the power supply's inductive output characteristics are identical to the characteristics of a real inductor. We can easily calculate the value of the equivalent power supply inductance, L_{PS}:

$$L_{PS} = \frac{X_L}{2\pi f} = \frac{Z_{OL}}{2\pi f} = \frac{10}{2\pi 200\,\text{KHz}}$$

$$L_{PS} = 8\mu H$$

Like any inductor, the power supply inductance generates a voltage, V_N, across the output when output current changes.

$$V_N = L_{PS}\left(\frac{dI_L}{dT}\right)$$

For a load change of 35 milliamps in 1 nanosecond (the current demand of a TTL gate during low-to-high output transition), the transient change in output voltage V_N is

$$V_N = L_{PS}\left(\frac{dI}{dT}\right)$$

$$= 8\mu H\left(\frac{35\text{mA}}{1\text{ns}}\right) = 280 \text{ volts}$$

Because of the load's shunt impedance, however, the output won't change more than a few volts.

Because of the regulator's inductive characteristics, the circuit designer must limit high-speed load-current

Continued on page 4

Continued from page 3

demands from the regulator and must set a maximum limit for dI/dT.

The designer can use noise limits to calculate the maximum rate of change in current (dI/dT) flowing into the power supply:

$$\text{Since } V_N = L_{PS}\left(\frac{dI_L}{dT}\right)$$

$$\frac{dI}{dT} = \frac{V_N}{L_{PS}}$$

For a 8-microhenry power-supply inductance and 24-millivolt peak noise voltage, the dI/dT must not exceed :

$$\frac{dI}{dT} = \frac{24mV}{8\mu H} = 3000\ \text{Amps/sec}$$
$$\text{or}$$
$$3mA/\mu sec$$

The Tektronix 7000 Series Engineering Instrument Specification limits to 10 mA/microsecond the load-current changes seen by the power supply. In our example, that limit, in turn, limits the output voltage change V_N to:

$$V_N = L_{PS}\left(\frac{dI}{dT}\right)$$
$$= 8\mu H\left(\frac{10mA}{1\mu sec}\right)$$
$$= 80 mV$$

Figure 4 shows a small-signal ac circuit equivalent for the model power supply shown in figure 1. At low frequencies, L_{PS} is a short circuit and the output impedance is essentially R_{PS} (10 milliohms in this example). At high frequencies, L_{PS} acts as an open circuit and the output impedance is R_O.

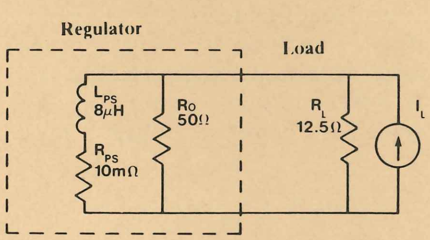


Figure 4. In this small-signal voltage-regulator equivalent circuit, L_{PS} represents the inductive portion of the output impedance.

In the middle frequencies, inductance is the major component of the impedance. We have ignored the inductance of the wires connected to the load, because this inductance is usually much smaller than the power supply inductance and thus insignificant in most cases.

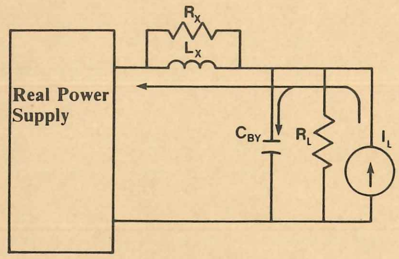


Figure 5. Bypassing and/or decoupling can be used to impede high-frequency currents flowing into the power supply. The transient current, I_L, divides between the power supply and the bypass paths, with most of the current flowing through the smaller impedance.

DECOUPLING AND BYPASSING

The designer may use either bypassing or decoupling to limit high-frequency currents (dI/dT) in the power supply. See figure 5. The high-frequency currents generated by the load-demands (represented by transient current source I_L) divide between the power supply and bypass paths. The current flowing in each path is inversely proportional to the path's impedance.

To decrease the high-frequency current in the power supply, the designer may either increase the power supply path impedance or decrease the bypass path impedance. Inserting a "decoupling" impedance (L_X or R_X or both) will increase the impedance of the power supply path. Increasing the value of the bypass capacitor will decrease the bypass path impedance. Although both techniques will decrease high-frequency current flowing into the power supply and reduce the noise voltage ((L)(dI/dT)) at the power supply output, decoupling will increase the noise generated at the load.

The current demand generates a noise voltage at the load that is directly proportional to the impedance it sees. This impedance is the parallel impedance of the two current paths. Adding a decoupling impedance in the power supply path increases the total impedance seen by the transient current source. The result is greater voltage at the load.

$$V_N = I_L Z$$

Though decoupling does increase load noise due to transient current demand, decoupling is useful for other applications. Decoupling will be further described in a later

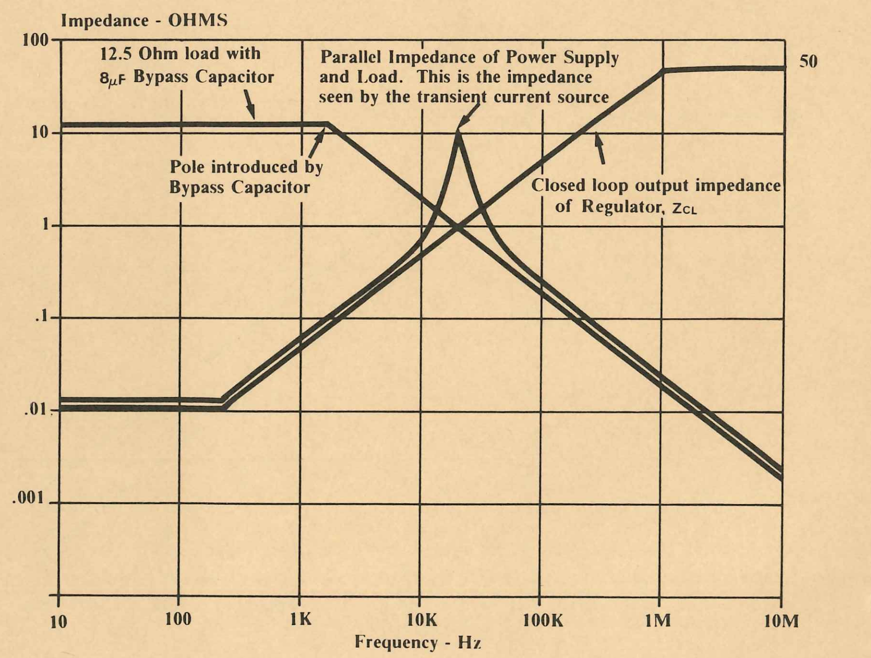


Figure 6. This is a graph of the power supply output impedance with a bypassed load. Any load connected to this supply sees the power supply as a parallel resonant circuit.

article. Bypassing, unlike decoupling, decreases noise at both the power supply and the load simultaneously. Bypassing reduces greatly the impedance seen by the transient current source I_L and diverts high-frequency currents from the regulator. However, bypassing also introduces a sharp resonant peak into the circuit's impedance characteristics. (See figure 6.) The equivalent inductance of the regulator and the bypass capacitor form a parallel resonant circuit which produces the peak. This resonant circuit has a high Q limited only by the load resistance.

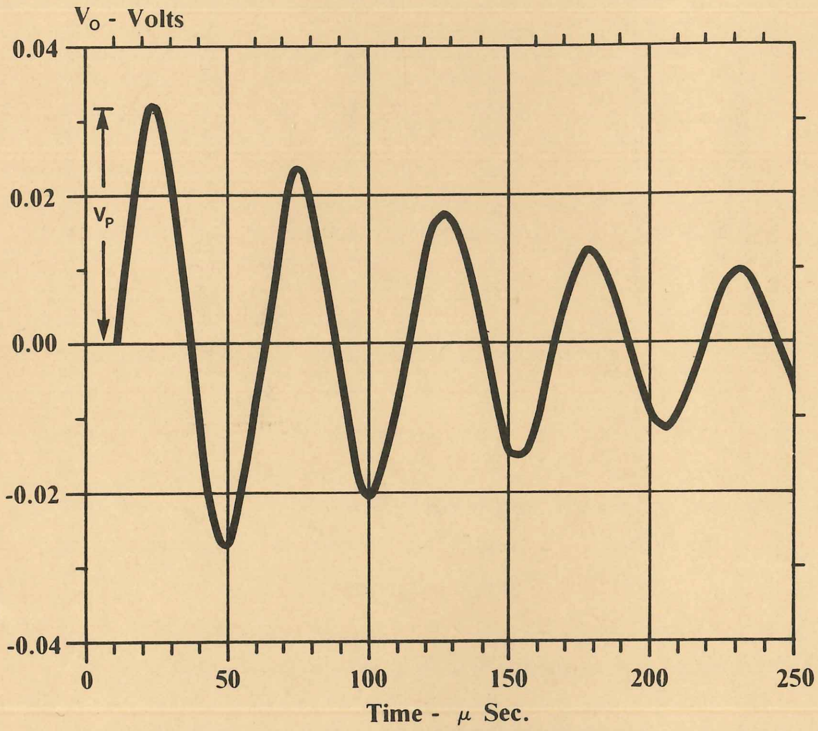


Figure 7. Shown here is the voltage regulator's response to a 35 mA load-current change. Bypassing limits the noise voltage at the load but causes ringing unless the power supply is properly damped.

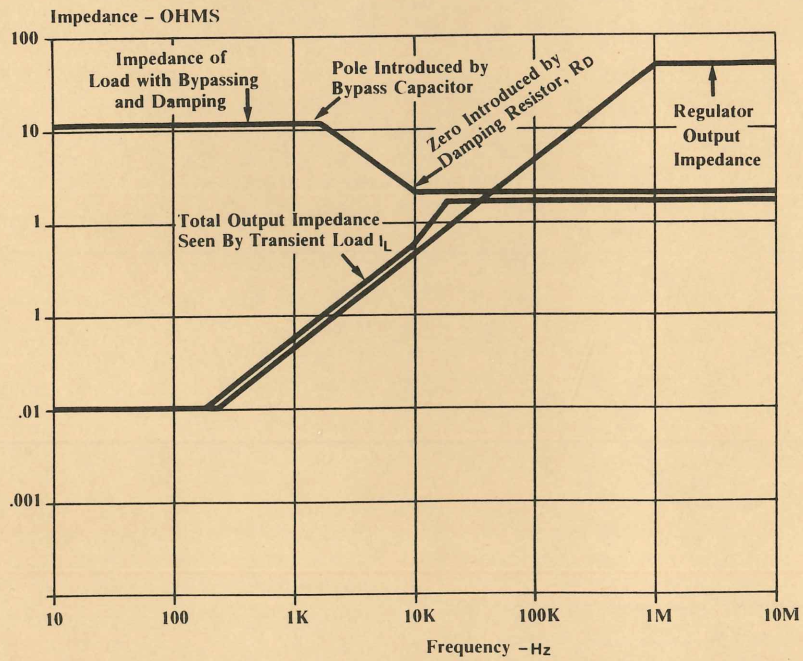


Figure 9. The impedance seen by the transient load, I_L, is a combination of the impedances of the load (R_L), the bypass capacitor (C_{BY}), the damping resistor (R_D), and the regulator (see figure 8).

The impedance of the power supply inductance (L_{PS}) and the bypass capacitor (C_{BY}, are equal at resonance. The impedance, Z_R, is:

$$Z_R = \sqrt{L_{PS}/C_{BY}}$$

And, for our example,

$$Z_R = \sqrt{\frac{8\mu H}{8\mu H}} = 1\text{ohm}$$

This value is useful for predicting the peak transient-response amplitude.

Figure 7 shows the bypassed power supply's response to a 35-milliamp current change. The maximum voltage, V_P) can be calculated thus:

$$V_P = \Delta I \sqrt{\frac{L_{PS}}{C_{BY}}} = 35\,\text{mA}\left(1\text{ohm}\right) = 35\,\text{mV}$$

Increasing C_{BY} or decreasing L_{PS} decreases the noise voltage generated at the load.

RINGING

Unfortunately, bypassing causes ringing. To control the ringing and improve regulator stability, the designer must damp the sharp resonant peak. The most effective solution is adding a damping resistor, R_D, in series with the bypass capacitor in the load. See figure 8.

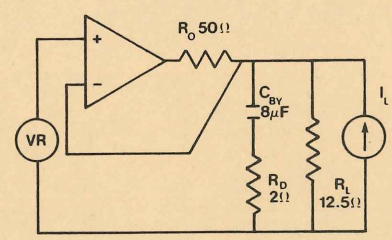


Figure 8. In this power supply with a bypassed and damped load, resistor R_D provides the damping.

The damping resistor creates a zero in the bypassing network impedance, compensating for the pole introduced by the capacitor (as shown in figure 9).

Satisfactory damping is obtained by adjusting the damping resistance R_D to

$$R_D = 2\sqrt{\frac{L_{PS}}{C_{BY}}} = 2Z_R$$

Continued on page 6

Continued from page 5

For our example this is 2 ohms. This value of R_D generates a zero at one-half the original resonant frequency and holds the impedance constant above that frequency (instead of decreasing it).

As shown in figure 9, the regulator's output impedance no longer has a resonant peak. Instead, the impedance increases to a maximum of 2 ohms at high frequencies. The transient response to the 35-milliamp current step (see figure 10) has almost doubled in amplitude with R_D. However, it is almost critically damped (compare this to figure 7).

The peak transient voltage, V_P, generated in a circuit with bypassing and damping, is a function of the resonant impedance, Z_R and the damping resistance R_D, and is proportional to the greater of the two impedances.

$$V_P = \Delta I \sqrt{\frac{L_{PS}}{C_{BY}}}$$

or

$$\Delta I R_D$$

whichever is greater

The designer may vary the value of R_D and C_{BY} to adjust the peak amplitude V_P and the damping over a wide range of needs. Increasing R_D decreases ringing but increases the peak transient amplitude. Increasing C_{BY} improves damping and simultaneously decreases the peak transient voltage V_P.□

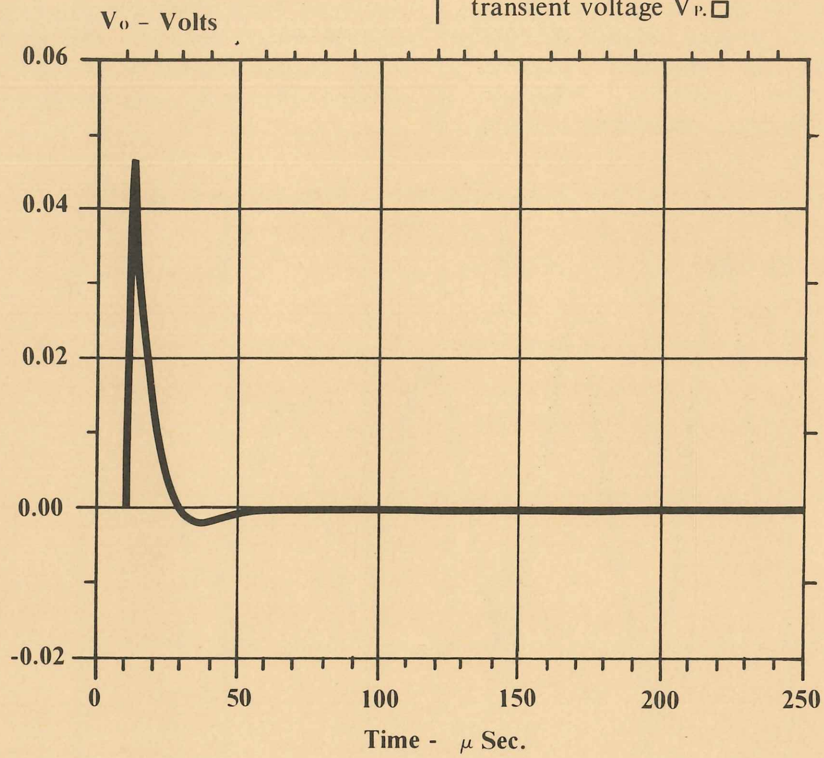


Figure 10. This graph is the power supply's time-domain response to a 35 mA load-current change in the damped circuit shown in figure 8.

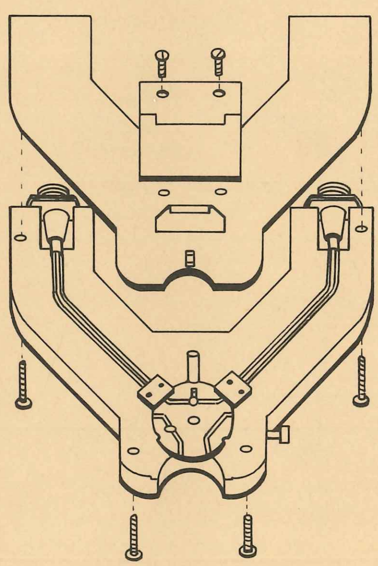
PATENTS RECEIVED

TRANSISTOR TEST FIXTURE

Casey Veenendaal, Display Device Engineering, ext. 7045 (Beaverton).

The transistor test fixture shown here accomodates automatic tests for "micro-T" high-frequency transistors. To measure the characteristics of these transistors, an operator must make pulse rise-time measurements of:

- a section of 50-ohm line that is exactly the same length as the lines connecting the transistor.



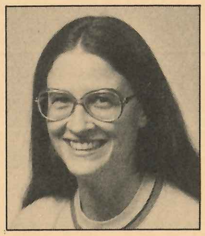
- the same 50-ohm line shorted to ground at the transistor terminals.

- the transistor in place.

Since the fixture is connected to a measurement instrument whose performance characteristics may drift, the operator must make phase-shift measurements in rapid succession. The patented fixture shown here has a rotatable disk which allows the operator to rapidly progress through the three test set-ups.

Without this fixture, the operator must build the shorted-line in the fixture, make a measurement, tear down the fixture, build the through-line, make a measurement, build a set of lines to connect the transistor, and finally make the third measurement. During the time required to build, measure and tear down short- and through-lines, the instrument's characteristics may drift enough to produce large measurement errors.□

HUMAN FACTORS IN . . . LEARNING TO USE TEK INSTRUMENTS



Novia Weiman, LDP Human Factors Engineering, ext. 7161 (Beaverton).

BEYOND THE PRODUCT

The easier Tektronix products are to use, the more valuable they are to the people who use (and buy) them. Logic Development Products human factors engineers are applying principles of the psychology of learning to make learning to use Tektronix instruments easier. This article briefly describes the background of their efforts.

TYPES OF LEARNING

Classical conditioning is learning in which new stimuli modify reflexes (automatic responses to stimuli). For example, if a bell rings just before a flash of light makes you blink, eventually you will blink each time you hear the bell whether or not the flash follows.

Classical conditioning has little value to users learning to operate our products. Classical conditioning is passive learning, but even production-line button-pushing requires more user involvement than that.

Operant conditioning is "learning-by-doing" when the doer can see the results. If flipping a switch causes a light to go on, it doesn't take long to learn the connection between the two events. Unfortunately, operant conditioning can lead a user to learn inappropriate actions too. For example, if your TV set turns on when you pound on it, you are more likely to try pounding in other situations.

Users of complex instruments do sometimes employ operant conditioning when learning how to

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> A decade divider is an arrangement of four cascaded binaries (flip-flop) so that for every ten input pulses, there is one output pulse. Consequently, when a frequency is applied to the input of the decade divider, the first binary divides it by two (since the first pulse switches the binary to the opposite state and a second pulse is required to return it to its original state) and again by two in the second binary (making a total division by four) and so on, with an expected total division of sixteen at the output of the fourth binary. The desired division by ten is obtained by a feed-ahead pulse to the fourth binary and feedback pulses to the second and third binaries ...

Figure 1. LDP human factors engineers have analyzed the readability of several instrument manuals as part of their effort to make Tektronix instruments easier for customers to use. The passage above is from the Hewlett-Packard 5245 Electronic Counter Service Manual. The Flesch Index rating for the passage is 35. (The index runs from 0 for "almost unreadable" to 100 for material that any literate person can read easily.) By contrast, the Flesch Index rating for *Time Magazine* is about 65. LDP human factors engineers believe the HP passage is too difficult for the expected user.

Reading Ease Score	Style	Typical Magazine
90 to 100	Very Easy	Comics
80 to 90	Easy	Pulp fiction
70 to 80	Fairly Easy	Slick fiction
60 to 70	Standard	Digests, Time, mass non-fiction
50 to 60	Fairly Difficult	Harper's, Atlantic
30 to 50	Difficult	Academic, scholarly
0 to 30	Very Difficult	Scientific, professional

Source: Flesch, Rudolph. How to Test Readability. Harper Brothers, N.Y., 1951, 6.

Figure 2. The Flesch Index rates printed material for reading-ease scores for a variety of magazines. The excerpt in figure 1 has a rating of 35, indicating it is too difficult for the intended reader: a busy service technician. In the table, 35 falls in the "scholarly" category.

Continued from page 7

use them. Users who ignore manuals and simply press buttons often learn this way. However, operant conditioning is a slow way to learn.

Observational learning is a third kind of learning. This is "learning-by-watching" rather than by doing. For example, when you buy a Tektronix terminal and attend a training class, you are using observational learning when watching the instructor demonstrate the terminal.

Observational learning is generally the most effective way to learn to use instruments, but combining operant and observational techniques is more effective. An example of the combination is watching someone perform a task and then performing the task yourself.

Customers employ both techniques when using our manuals. Reading a procedure is similar to watching another person perform a task. Performing the procedure reinforces the observational learning.

LDP human factors engineers have tested the readability of several manuals. In one Tektronix software manual, the reading grade level was 14 ... that is, 14 years of formal education (high school plus two years of college). The Flesch Index rating was 39. (The Flesch Index rates reading material on a scale of 0 for almost-unreadable text to 100 for text that any literate person can read easily.)

MANUAL READABILITY

Also tested was a Tektronix instrument manual's instructions for operating front panel controls, for connecting connectors, and for interpreting the instrument's displays. The manual's reading grade level was 16 (college senior), which may be several grade levels too high for the intended user. With results such as these, LDP human factors engineers are evaluating Tektronix manuals to ensure more readable manuals for future products.□

MP ERROR DISPLAY USING THE 851 DIGITAL TESTER

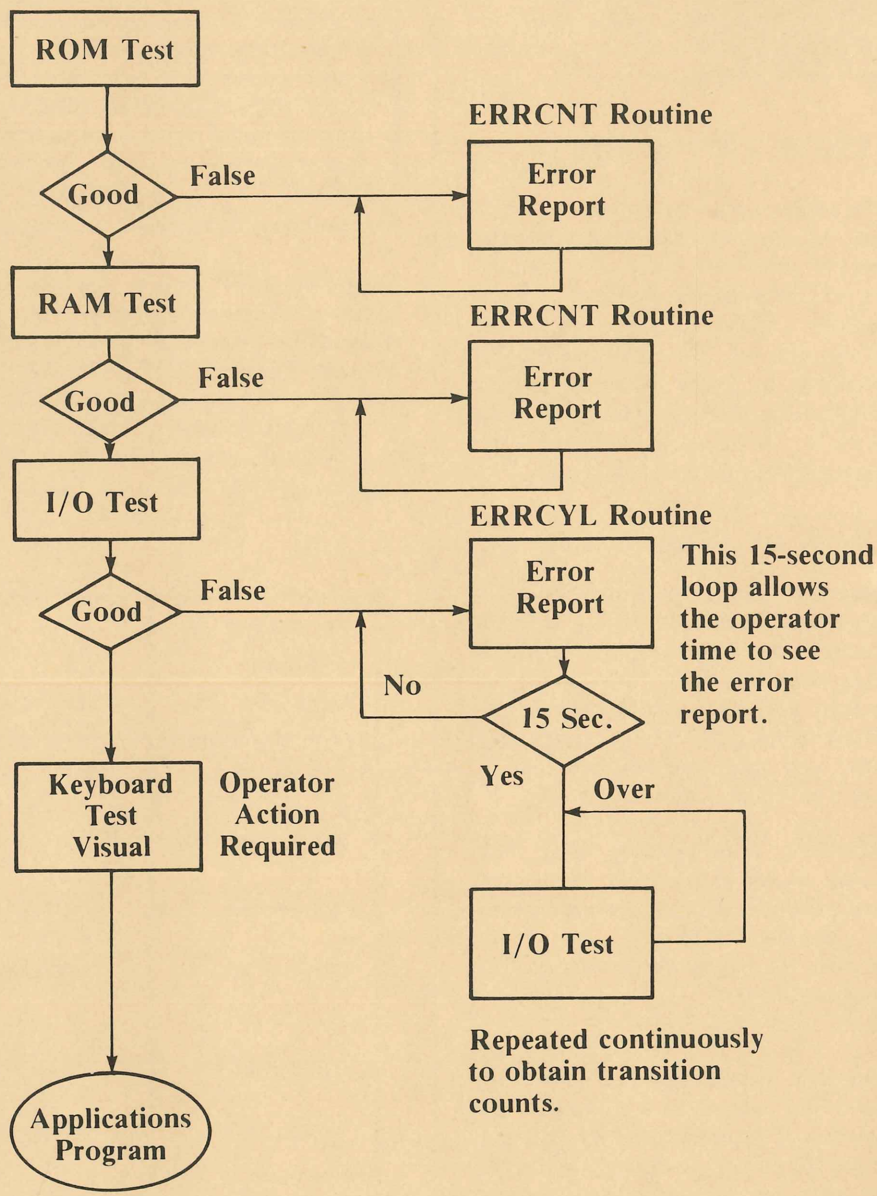
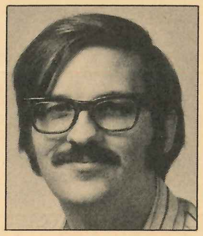


Figure 1. Diagnostic programs typically require two types of error reporting: reporting "fatal" errors and reporting errors to help the servicer further isolate a problem. The ERRCNT routine shown in the figure generates a frequency ratio on two output pins of the microprocessor in the instrument being serviced. The ERRCYL routine also generates a frequency ratio on the output pins, but only for 15 seconds. Next, ERRCYL instructs the instrument diagnostic to continuously exercise the instrument's hardware, thus allowing the servicer to further isolate the problem.



David Bennett, SID Firmware, (formerly with SID Applications Engineering), ext. 5634 (Beaverton).

When servicing microprocessor-based instruments, the first task is verifying the microprocessor's "kernal" (the clocks, power supply, and address and data bus lines). The servicer should next check RAM, ROM and I/O with a diagnostic program that resides in the instrument's ROM. The diagnostic program sends error messages (via the I/O system) to the instrument's display device. Unfortunately, some microprocessor-based instruments either have no displays or the displays aren't suitable for error messages because they don't provide enough information to identify the error condition. Besides, the I/O system may be part of the service problem.

USING THE 851

There is a way to display error messages with the 851 Digital Tester, a portable, 22-function service instrument. A major benefit of this method is that it requires only the 851 Tester and a short error routine added to the instrument's diagnostic program. There are other benefits: the error indication is stable, the 851 is easy to set up, and the method works with most microprocessors. And, although the 851 is used here as a display device, the 851 is primarily a general-purpose troubleshooting and repair tool.

For simplicity, the method assumes that the reported errors are "hard" (not intermittent).

THE METHOD

The method is simple: create a frequency ratio on two of the microprocessor's output pins. One pin pulses at a lower frequency than the other pin. The ratio of pulses on the pins is determined by an error routine variable. Each variable value represents a given error condition. Table 1 shows which pins may be chosen depending on the microprocessor. The error routine must define the state of the output pins at all times. A program loop creates the pulses and an instruction outside the loop stimulates the output pin with the lower frequency signal. The diagnostic programmer can create input to the error routine to control the loop's execution length and thus identify each kind of error with a given ratio.

	8080	8085	6800
Channel A input (high frequency)	SYNC	ALE	VMA
Channel C input (low frequency)	WR	WR	R/W

WR= signal indicating data transfer from CPU to memory or I/O; VMA = valid memory address on bus; ALE = address latch enable; R/W= signal indicating data transfer between CPU and memory. SYNC= signal indicating the beginning of each machine cycle.

Table 1. Using an 851 Digital Tester, a service technician can measure the output of the microprocessor pins shown here. These measurements indicate error conditions for instruments that don't have displays or whose displays may be part of the service problem. The pin outputs (and therefore the indicated error code) are determined by a diagnostic program stored in ROM in the instrument being serviced.

851 SETUP

To setup the 851, the servicer attaches the CHANNEL A probe to the microprocessor high-frequency output pin, and then attaches the CHANNEL C probe to the low-frequency output pin, and selects these control settings:

CONTROL	SETTING
FUNCTION	FREQ A/C
SLOPE	POS for both channels
THRESHOLD	TTL (detent) for both channels
DISPLAY	NORM
RANGE	AUTO
INPUT FILTER	OFF

Figure 2 diagrams the error routine ERRCNT. An error code loaded into the A register determines the output ratio. When the register reaches zero, the microprocessor pulses the lower frequency pin and the loop repeats. This produces a stable, predictable frequency ratio.

Figure 1 diagrams a typical diagnostic program. As indicated in the figure, diagnostic programs typically require two types of error reporting. The first type, ERRCNT in our example, reports fatal errors the ("fatal" means the serviced instrument shouldn't be used when the error is present). ERRCNT is also useful when the operator no longer needs to isolate the problem (for example when a ROM can be uniquely isolated by the diagnostic program alone).

The second type of error reporting, as illustrated with ERRCYL, is useful when the servicer does need to further isolate the problem. For example, in figure 3, a multilevel logic string in ERRCYL reports the error but for only 15 seconds. The diagnostic program then runs in a continous loop to exercise the hardware. To further isolate a problem, the servicer may then use transition-counting with the 851.

Figure 3 lists the second error routine, ERRCYL. This routine exercises the microprocessor after indicating an error condition for 15 seconds. ERRCYL'S method of creating a ratio is basically the same as the ERRCNT procedure. In ERRCYL, however, the routine returns control to the diagnostic program to continue exercising the hardware.

FOR MORE INFORMATION

For more information about servicing programs for the 851 Digital Tester, call Leslie Wischmeyer on ext. 8-821-212 (Town Center).

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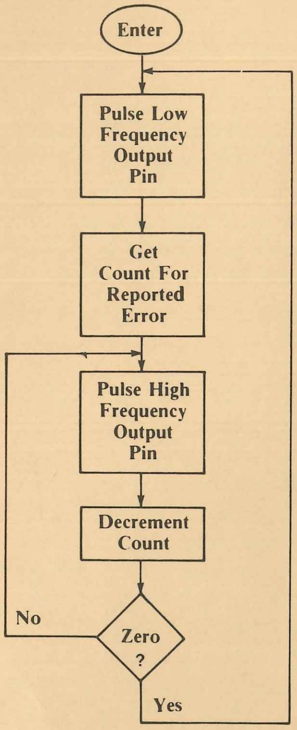
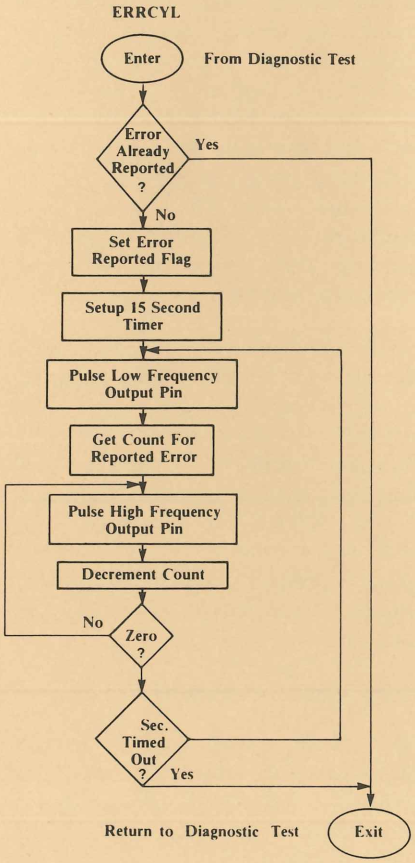
ERRCNT Continued from page 9




```
*********************************************************************
*
*                  ERROR COUNT OUTPUT
*
*********************************************************************
*
*
*          OUTPUTS PULSES ON SYNC PIN
*
*          COUNT IS GATED BY WR- PIN
*
*          INPUT: PULSE MULTIPLIER IN ACCUMULATOR
*
*
ERRCNT     LXI      H,IOSET       SETUP PULSE HIGH POINTER
           MOV      B,A           SAVE PULSE COUNT
*
PULSE      MOV      M,A           PULSE WR- PIN
           MOV      A,B           RESTORE COUNT
COUNT      DCR      A             DECREMENT PULSE COUNT
           JNZ      COUNT         COUNT PULSES ARE ON THE SYNC PIN
*
           JMP      PULSE         AND START COUNT
*
```

Figure 2. As shown in the flow diagram, error routine ERRCNT continuously reports an error. This version of ERRCNT was written for an 8080 microprocessor.

ERRCYL




```
*********************************************************************
*
*                  ERROR CYCLE OUTPUT
*
*********************************************************************
*
*
*          OUTPUTS ERROR COUNT ONCE FOR 15 SECONDS
*          AND THEN RECYCLES THROUGH THE I-O TESTS CONTINUOUSLY
*
*
ERRCYL     LDA      CYCLF         FETCH CYCLE FLAG
           ORA      A
           RNZ                    ERROR HAS BEEN REPORTED,CONTINUE TEST
*
           INR      A             ELSE UPDATE CYCLE
           STA      CYCLF
           POP      PSW           RESTORE STACK
           LXI      H,IOSET       SETUP RETURN ADDRESS
           LDA      FAIL          FETCH FAIL COUNT
           MOV      B,A           AND SAVE IT
*
           LXI      D,$00         SETUP 15 SECOND
*                                 TIMER COUNT
           JMP      PULSE2
*
TIMCHK     DCX      D             CHECK TIMER
           MOV      A,E
           ORA      D
           JNZ      PULSE2
           PCHL                   TIMED OUT RECYCLE I-O TESTS
*
PULSE2     MOV      M,A           PULSE WR- PIN
           MOV      A,B           RESTORE COUNT
COUNT2     DCR      A             DECREMENT PULSE COUNT
           JNZ      COUNT2        COUNT PULSES ARE ON THE SYNC PIN
*
           JMP      TIMCHK        DONE. CHECK TIMER
```

Figure 3. Error routine ERRCYL reports an error condition for 15 seconds and then enables the diagnostic program to continously exercise the hardware, thus allowing the servicer to further isolate the hardware.□

DESIGNING FOR SERVICE

Chet Heyberger, SID Applications Engineering, ext. 8-821-209 (Town Center).

RISING COSTS

In recent years the electronics industry has suffered from rapidly rising costs. One factor contributing to increased expenses is service costs which are rising faster than other costs. Because service budgets have a major impact on profits, at Tektronix we are trying to lower our service costs as well as our customers' service costs.

Where does all that service money go? As you can see in figure 1, about half of a typical service budget is for people, mostly for technical people. This cost is rising rapidly: increased demand, decreased supply (the military, for example, no longer trains as many service technicians as it once did), and "normal" inflation are contributing factors. Other costs include travel, telephone, administration, facilities, training, documentation, and third-party maintenance charges. These costs have also risen.

Surprisingly, service instruments account for only 2% of the typical service budget. In the Service Instruments Division, we believe that the best way to hold down service costs is investing in service instruments and designing products to be serviced by these instruments.

THE SERVICER

To design for serviceability, the designer must understand the service world: who the servicer is, the problems encountered, service procedures used, and the tools available.

Most service technicians have either two-year or four-year technical degrees, but little experience except with the few products for which they have been trained. The training for

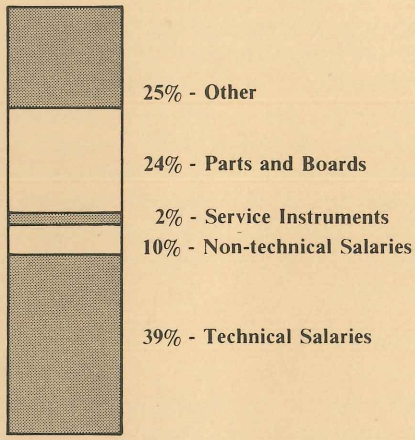


Figure 1. Almost half of a typical electronic manufacturer's service budget is for labor, but only 2% is for service instruments. Design engineers can reduce service costs by designing products for more efficient servicing. One way to achieve that goal is to include diagnostic firmware tailored to a specific service instrument.

each product may be as much as two weeks or as little as a couple of days. Unfortunately, because job turnover is high, training benefits are short-lived.

FIRST-LINE CALLS

The servicer handles about 95% of the initial customer service requests and has to pass the rest on to specialists. The servicer encounters four kinds of first-line calls: (1) customer assistance; (2) adjustment, calibration and installation; (3) electromechanical troubleshooting; and (4) electronic troubleshooting.

CUSTOMER ASSISTANCE

Customer assistance includes training, consultation and general hand-holding . . . together they require about 21% of the typical servicer's time. Design-for-service affects even this kind of first-line call. For example, the product designer can modify engineering verification programs to give the customer an operation-verfication program and to provide the servicer with troubleshooting diagnostics.

Other product features that can help the servicer (and therefore the customer) are built-in self-test and calibration functions. Complete and easy-to-use manuals also will build the customer's confidence.

ADJUSTMENTS

To install, adjust and calibrate a variety of products, the servicer may need a wide variety of service tools. Even for a given product, the servicer may, for example, need a diagnostic program, a volt/ohm meter, a digital multimeter, and a counter.

ELECTROMECHANICAL TROUBLESHOOTING

The servicer may use many adjustment and calibration tools for electromechanical troubleshooting as well. Design-for-service guidelines apply to troubleshooting and as well as adjustments and calibrations.

For example, the designer should provide safe and easy access to parts to be serviced. If exercising a moving part is a service requirement, the designer should include the exercise in the product design so the servicer won't have to carry extras to the site. And, of course, including test points greatly helps the technician locate and identify the trouble.

ELECTRONIC TROUBLESHOOTING

Modern equipment like self-regulating power supplies and stepper motors requires less calibration and adjustment time than variable power supplies, mechanical keyboards and escapement mechanisms. However, electronic troubleshooting takes more of the servicer's time than in the past because more equipment now is digital and digital instruments are often the most difficult to troubleshoot.

Electronic troubleshooting can be divided into analog and digital. Design-for-service for analog problems requires such aids as test points that allow the servicer to

Continued on page 12

Continued from page 11

check functional blocks. Comparing test point voltages to predetermined values is a convenient way to isolate a problem.

Digital servicing is far more complicated than analog servicing because digital products often use many non-repetitive signals. Further, transmitted digital signals may be extremely long and complex.

ABSTRACT TROUBLESHOOTING

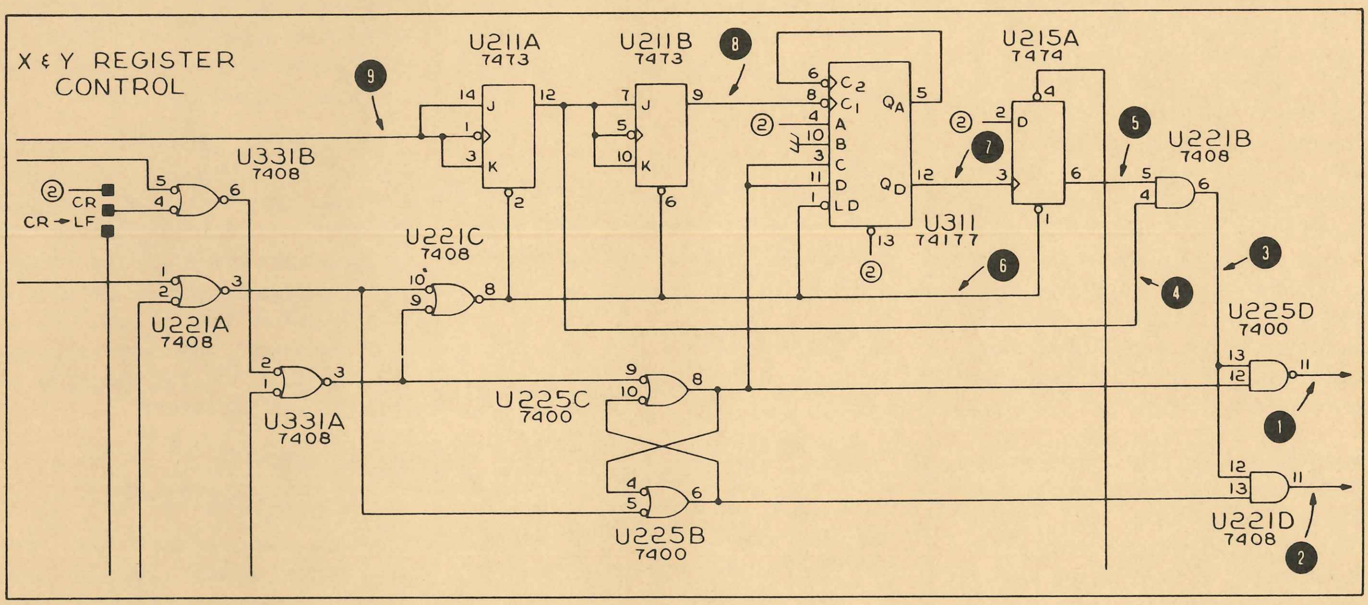
Fortunately, there are tools for digital troubleshooting and the most efficient tools allow "abstract troubleshooting."

All troubleshooting compares a system-under-test to a correctly-operating system. The servicer may make the comparison to an identical system sitting alongside the one being serviced, to a model (on annotated schematics) of the correctly-operating system, or to a model in the servicer's mind. Or, in the case of abstract troubleshooting, the comparison may be made to diagnostics or signatures that represent the correctly-operating system. With abstract troubleshooting, the servicer doesn't need a complete model of the product. That's especially important because today's products are often extremely complex.

EXAMPLES

Here are some examples of designs for abstract troubleshooting. Figure 2 shows part of the Tektronix 4006-1 X and Y register control troubleshooting procedure. The schematic identifies the test points for this procedure only and shows where the servicer should attach the service instrument's probes. The troubleshooting procedure uses **transition-counting**. The transition count for a given test point is unique. The servicer compares the measured count to the count shown on the troubleshooting tree. (The Tektronix 851 Digital Tester, for example, allows the technician to use transition-counting).

A second abstract-troubleshooting technique is **signature analysis,** a technique available with a few products on the market. Signature analysis is another gated-function for counting events. As with transition counting, signature analysis requires an exercise routine to send a repeatable bit-pattern through the circuit being tested. The exercise routine then shifts the output pattern through a register, transforming the pattern into a signature which the servicer compares to schematic



4006 X & Y REGISTER TROUBLE SHOOTING

(Set 851 FUNCTION switch to A TRNSN (B—C) and attach probes B and C as indicated on schematic. Use probe A on test points.)

1: If (TP1 $\neq$ 0), then 2
Else: If (TP2 $\neq$ 1204), then 2
Else: Run X & Y deflection Test

2: If (TP9 $<$ 36608 or $>$ 36672), then 2.1
Else: Run oscillator test
2.1: If (TP7 $<$ 946 or $>$ 948), then 2.1.1.
Else: If (TP8 $<$ 15464 or $>$ 15480), then replace U211 and return to 2
Else: Replace U311 and return to 2
2.1.1: If (TP3 $\neq$ 1204), then replace U215 and return to 2
Else: Replace U221 and U225 and return to 2

Figure 2. This schematic and troubleshooting tree are an example of one kind of abstract troubleshooting: transition-counting. The transition count for a given test point is unique. The servicer compares the measured count to the count shown on the troubleshooting tree (bottom).

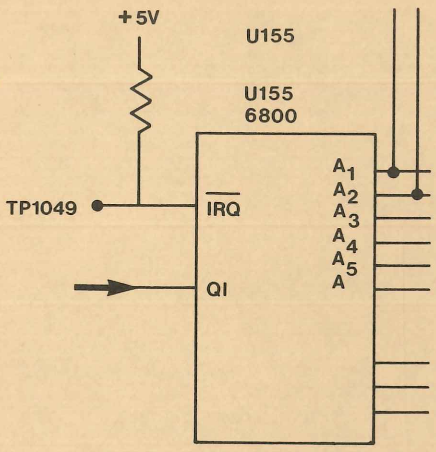


Figure 3. Here's another example of design-for-service. The Tektronix 832 Data Comm Tester design team provides control point TP1049 for the microprocessor. Pulling down the Interrupt Request Line (through TP1049) turns on the instrument and starts the 832's diagnostic.

notes. A disadvantage of signature analysis is that the circuit tested must have synchronous clocking.

Most abstract-troubleshooting techniques require a stored exercise routine. But that isn't a drawback, because the designer can use the ROM already in the microprocessor-based instrument. For example, Service Instruments Division engineers are using a Tek 832 Data Comm Tester diagnostic routine that checks each RAM chip and displays the faulty RAM's identification number. The number is marked on the RAM circuit board, making identification easy.

The routine has 121 lines of code and includes a 16-second memory test. With a little extra effort, SID engineers converted this engineering verfication program into a routine for customers and servicers.

In another example of 832 Data Comm design-for-service, the design team provided a control point (TP1049) for the microprocessor shown in figure 3. The test point connects to the Interrupt Request Line (IRL), which, when pulled down, turns on the instrument and automatically starts the diagnostic routine. In other words, the technician can run the diagnostic routine even if the product's keyboard doesn't work.

OLD AND NEW

"Design-for-service" doesn't mean the designer must assume that the servicer will use only state-of-the-art service instruments. In a recently produced Tektronix processor board, designers provided a jumper which, when moved to the service position disables the peripherals and causes the microprocessor to clear a memory location and start a program loop which toggles the address lines. This allows the servicer to check the lines with an instrument as simple as a logic probe.

THE BIG PICTURE

All the techniques we've discussed assume that electronic trouble-shooting is the whole picture. It's not. Even digital systems sometimes require adjustments and calibrations, customer assistance, and electromechanical trouble-shooting. So, the ideal service instrument addresses all those functions and includes both abstract and analog troubleshooting aids.

There is a need for a portable, general-purpose service instrument. The multifunction Tektronix 851 Digital Tester can fill that need ... especially when project engineers consider service, service tools, and the servicer when designing Tektronix products.

FOR MORE INFORMATION

For more information about Tektronix service instruments or about designing-for-service, call any of these people in SID Applications Engineering at the Town Center complex:

- Paul Kristof, ext. 203.

- Leslie Wischmeyer, ext. 212.□

WORKSHOP ON HIGH SPEED A/D CONVERSION

A workshop on High-Speed A/D Conversion was held October 16 and 17, 1978, at the Portland Hilton Hotel. Conceived and organized by Jon Birck (Data Acquisition Research, Tek Labs), the workshop brought together about fifty experts on high speed A/D conversion for a free exchange of ideas.

The unsponsored workshop consisted of four sessions: Real-Time Conversion, Scan Conversion, Sample-and-Hold, and a discussion session. There were 16 presentations; they described design and analysis of devices and systems that have conversion rates greater than 100 megasamples per second. Technologies such as GaAs converters, electro-optic converters, silicon bipolar converters, charge-coupled device scan converters, electron-bombarded semiconductor scan converters were represented.

Since there will be no publication of material presented at the workshop, Tektronix engineers are invited to attend a workshop review on Thursday, November 16. The three attendees from Tek, Jon Birck, Larry Riley (Signal Processing Devices, Tek Labs), and George Wilson (Bipolar IC Design, Tek Labs) will discuss the workshop presentations. To reserve a place at the review, please call Maureen Richardson on ext. 5592.□

NEW EAC MEMBERS

In August, seven new members joined the Engineering Activities Council. Five Council members, who have been with the Council since November, 1976, left the Council this summer (Council members serve 18-month terms). The new members are Bruce Ableidinger, Dave Armstrong, Hal Cobb, Tim Flegal, Mike Reiger, Lynn Saunders, and Jim Tallman. Table 1 lists the Council members.

FORUMS

The Council's objective is to provide engineers with a forum in which to present directly to multiple levels of management what engineers themselves consider to be important in technology. To fulfill its charter, the Council has sponsored 11 Engineering Forums ("Engineers Talk to Managers"). In each forum, four or five engineers discuss, from an engineering viewpoint, the progress and problems of new technology. The audience consists of approximately 125 corporate, divisional and departmental managers. Attendance is limited by the capacity of the auditorium, but the forum presentations are published in **Forum Report** and distributed over the **Engineering News** mailing list. Eight forum reports have been distributed so far. Table 2 lists the forums which have been presented. The forum cochairmen, who are Council members, select forum participants from the engineering community.

FOR MORE INFORMATION

To suggest a forum topic or if you have questions about the Council, call one of the members (table 1 shows their phone numbers).

Engineering Activities Council members and support people: *standing, left to right,* **Joel Leaman (former member), Mike Reiger, Lynn Saunders, Jon Mutton, Bob Burns, Tim Flegal, John Addis, Dave Armstrong, Mike McMahon.** *Seated,* **Robert Chew, Jim Tallman, Bill Walker, Karen Hall (secretary), Steve Joy (chairman), Mike Boer, Hal Cobb.** *Kneeling,* **Burgess Laughlin (support), Phil Crosby, Hock Leow, Binoy Rosario, and Cal Diller. Council members not present: Bruce Ableidinger and Bob Oswald.**

Bruce Ableidinger	LID, LDP Engineering	7161
Jim Tallman	LID, 7000 Series Engineering	7076
Dave Armstrong	SID, Accessories Engineering Design	5244
Cal Diller	SID, Engineering	7889
Hal Cobb	Tek Labs, Hybrid Circuits	5362
Steve Joy	Tek Labs, Digital Products Coordination	5285
Hock Leow	Tek Labs, Display Research	5654
Mike Rieger	Tek Labs, Signal Processing Resources	6907
Binoy Rosario	Tek Labs, IC Design	6362
Phil Crosby	Communications, TV Engineering	7079
Mike McMahon	Communications, FDI Engineering	5678
Tim Flegal	MSD, TM500 Engineering	1559
Bob Oswald	MSD, TM500 Engineering	1535
Jon Mutton	IDG, IDP Engineering	2648
Lynn Saunders	T & M Operations, Software Engineering Resources	5616

Table 1. Bill Walker, Test and Measurement group vice president, selects Council members from a list of candidates who are nominated through three channels: (1) by managers of engineering departments, (2) by current Council members, or (3) through the candidates' own initiative (Engineering News articles announce Council openings). The current Council members are listed here.

FORUMS		CO-CHAIRMEN
1.	General Purpose Interface Bus	Paul Williams, Robert Chew
2.	A-D and D-A Converters	Bob Nordstrom, Mike Boer
3.	Video Display Techniques	Steve Joy, Phil Crosby
4.	New Technologies: I	John Addis, Bob Burns
5.	New CRT Technologies	Bob Oswald, Cal Diller
6.	Creative Microprocessor Hobby Projects	Dave Chapman, Joyce Lekas
7.	Managers Talk to Engineers	Mike Boer, John Mutton
8.	Microprocessor Design Pitfalls	Robert Chew, Paul Williams
9.	New Technologies: II	Hock Leow, Binoy Rosario
10.	Packaging	Bob Burns, Cal Diller
11.	Creative Microprocessor Hobby Fair Projects: II	Steve Joy, Hock Leow

Table 2. In the last two years, the Engineering Council has sponsored 11 forums in which engineers presented (to corporate, divisional, and departmental managers) engineers' views of the problems and progress of new technology at Tektronix. The forum presentations are published in Forum Report, which is distributed over the Engineering News mailing list. For a copy of a forum report listed here, call T&M Publicity on ext. 6792.□

NEW TEK GPIB STANDARD

In July, 1978, Technical Standards published the latest revised edition of **GPIB Codes and Formats,** a Tektronix standard that implements the IEEE488 standard. For a copy of the standard, call Reprographics on ext. 5577.□

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Cover design: Joe Yoder.

Why EN?

Engineering News serves two purposes. Long-range, it promotes the flow of technical information among the diverse segments of the Tektronix engineering and scientific community. Short-range, it publicizes current events (new services available and notice of achievements by members of the technical community).

Contributing to EN

Do you have an article or paper to contribute or an announcement to make? Contact the editor on ext. 6792 or write to 19-313.

How long does it take to see an article appear in print? That is a function of many things (the completeness of the input, the review cycle and the timeliness of the content). But the *minimum* is five weeks for simple announcements and about eight weeks for major articles.

The most important step for the contributor is to put his message on paper so that the editor will have something to work with. Don't worry about organization, spelling and grammar. The editor will take care of those when he puts the article into shape for you.

ELECTRONICS COMPONENTS CONFERENCE

The sponsors of the 29th Electronics Components Conference (the Electronic Industries Association and the IEEE Manufacturing Technology group) are calling for papers for the May 14-16, 1979 conference. The deadline for the 500-word abstract and extended outline is November 3, 1978; final papers are due February 23, 1979.

For more information and for assistance in producing your paper, call T&M Publicity on ext. 6792.

All papers and articles to be published outside Tektronix *must* pass through the Publicity department for confidentiality review. Further, the department interfaces with Patents and Licensing to make sure patent applications have been filed for all patentable designs discussed in the paper or article. Authors working in IDG can first contact the IDG Publicity department for assistance (ext. 2343). If you have a question about confidentiality or if you need assistance with an article or paper, call 6792.□

HOOK AND PC BOARDS

Wally Doeling and Bill Mark (Electrochemical Engineering, T&M Operations) authored "Hook and Other Dielectric Properties of Printed Circuit Laminates," a paper for the Printed Circuit World Convention in London in June, 1978. For a copy of the article, call Wally Doeling on ext. 6581 (Beaverton).□

DEVICE TEST PROCEDURES

Bob Renes (SID Engineering) and Trent Cave (STS Engineering) authored "Are Your Device Test Procedures Adequate?," an article for the March/April issue of **Evaluation Engineering.**

For a copy, call Trent Cave on ext. 1203 (Walker Road).□

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