TEKTRONIX

TEKSCOPE

SEPTEMBER 1971

CLEAR

simple operation

$|x|^y$

$\sqrt{x^2+y^2}$

$+$

one key programming

$=$

no need for complex computer language

CLEAR

REMOTE

DEFINE
$f(x)$

- a programmable desktop calculator
- the R1340 data coupler
- the 7D14 counts current to minimize circuit loading
- regulated power supplies as operational amplifiers

Cover: The front cover bears a message —did you see it? It says, "Simple operation plus one key programming equals no need for complex computer language." It means it doesn't take an expert to use the Scientist 909.

the TEKTRONIX® Scientist 909: a powerful, programmable desktop calculator

By Dave Takagishi, Electronics Engineer
Calculator Products Division

For the first time, it is unnecessary to learn a complicated machine language in order to operate a powerful desktop calculator. The TEKTRONIX Scientist 909 (and its companion, the Statistician 911) speaks the universal language of mathematics, substituting a simple keyboard language for complicated machine languages in scientific calculators.

This new calculator incorporates a powerful keyboard that is unmatched for simplicity of operation.

OPERATION BY MATHEMATICAL EXPRESSION

Mathematical expressions are entered directly as they would be written in equation form, using parenthesis if desired. For example, to solve the equation

$$(a - b)^{(c \times d)} \times \frac{(e + f)}{(g - h)} =$$

where a,b,c. . . .h are variables of the user's choosing.
Press:

[CLEAR] [(] a [−] b [)] [|x|^y] [(] c [×] d [)] [×] [(] e [+] f [)] [÷] [(] g [−] h [)] [=] answer

ONE-VARIABLE FUNCTION KEYS

Trig, Log, x^2, $\frac{1}{x}$, $\sqrt{x}$, and other one-variable function keys operate directly on the number in the display. For example, to find:

$$\sin h \frac{1}{(\ln \cos a)^2} \qquad \text{for } a = 36.5°$$

Press:

[CLEAR] [DEG ● ● RAD] 36.5 [cos x] [ln x] [x^2] [$\frac{1}{x}$] [hyper] [sin x]

Read the answer, **+644839326.7**

TWO-VARIABLE FUNCTION KEYS

Two-variable function keys such as [$|x|^y$] and [$\sqrt{x^2+y^2}$] operate on the display as the first variable x, and on the next entry or expression as the variable y. For example, to find:

$$a^b + \sqrt{c^2 + d^2 + f^2}$$

Press:

[CLEAR] a [$|x|^y$] b+c [$\sqrt{x^2+y^2}$] d [$\sqrt{x^2+y^2}$] f [=] ans.

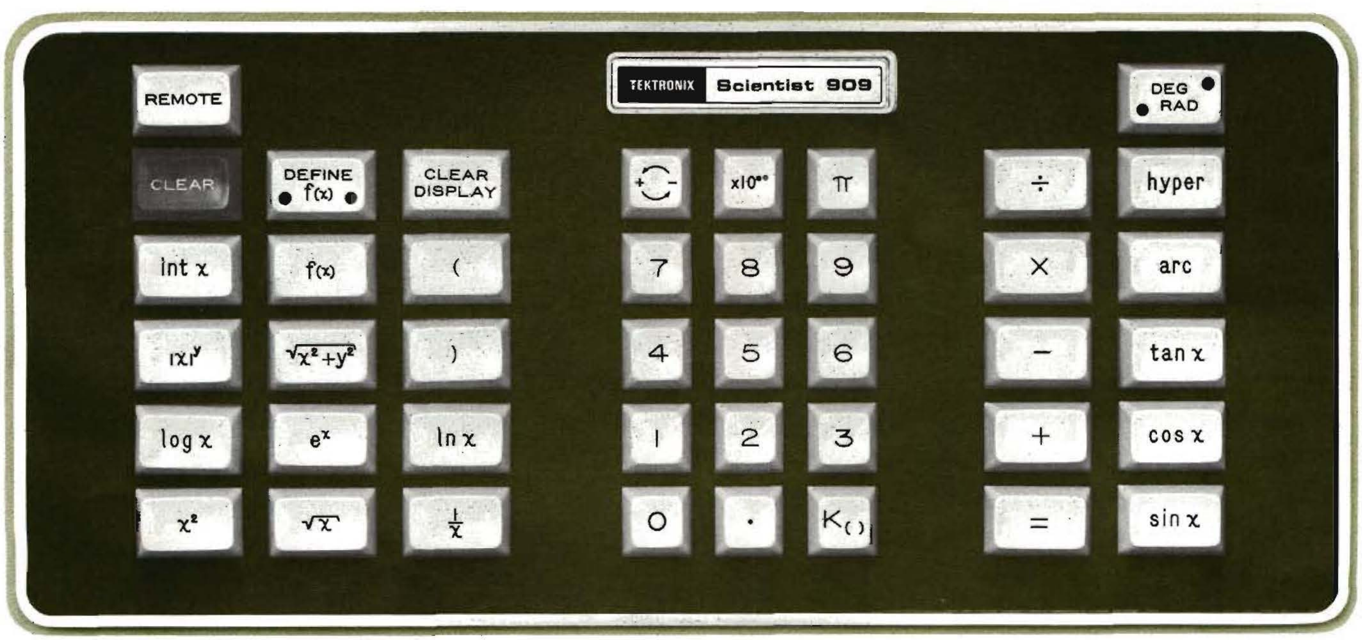
MEMORY STORAGE

The TEKTRONIX Scientist 909 has memory storage and recall that is extremely easy to operate. Any number in the display can be stored and identified with a two digit constant by pressing [=] [K( )] followed by the two subscript digits, 00 through 25.

For example, to display 17 and store it in register number 21

Press:

[CLEAR] 17 [=] [K( )] 21



The powerful Scientist 909 keyboard provides access to more mathematical functions than any other machine with fewer total keys.

The stored number (17 in the above case) can be recalled to the display again and again at any later time by pressing [K()] and the two subscript digits (21 in the above case). These recalled numbers can be used in all keyboard operations just as new digit entries are used.

Example:

$$\left[(3 \times K_{00} + K_{01}^2) \times 7 + \sin K_{00}\right] \times K_{02} = K_{03}$$

Indirect subscript addressing allows the Scientist to automatically sequence and operate on all stored constants. The number in the display is stored and identified with indirectly addressed subscripts by pressing [=] [K()] [K()] followed by two digits.

Example: Let $\pi =$ constant indirectly addressed as K_{17}. Pressing [π] [=] [K()] [K()] 21

will label $K_{17} = 3.141592654$ if $K_{21} = 17$ (from previous example). Subsequently whenever pressing [K()] [K()] 21, π will appear in the display.

PROGRAMMING

A "learn program" key is included on the Scientist 909 keyboard. While this key, [DEFINE ●f(x)●], is activated, the calculator is in a learn mode in which every key stroke (up to 256 steps) is memorized. These memorized key depressions may be automatically repeated at any time by pressing the key called [f(x)] (thereby eliminating repetitive keying sequences). This feature may be used to define your own special function key. For example, to define your own special inverse Gudermannian function key where

$$f(x) = \ln \tan\left(\frac{x}{2} + \frac{\pi}{4}\right)$$

Press:

[DEFINE ●f(x)●] [÷] 2 [+] [π] [÷] 4 [=]

[tan x] [ln x] [DEFINE ●f(x)●]

Now use the [f(x)] key like any other function key operating on one variable.

In addition to the above type of programming, which is essentially linear (no branching or looping) the TEKTRONIX calculator family includes an "add on" programmer, the 926.

This programmer unit provides the branching and looping features of a small computer and will store 512 program steps in its internal MOS storage. The contents of this storage can be transferred to a tape cartridge which installs in the Programmer. Each cartridge holds up to 10 blocks of these 512 step programs. The Programmer 926 combined with a TEKTRONIX Scientist 909 or Statistician 911 Calculator can accomplish most tasks a scientific computer can, with the exception of those tasks requiring very large data storage.

APPLICATIONS OF THE SCIENTIST 909

Applications for the TEKTRONIX Scientist 909 span virtually every discipline and profession where mathematics is used. Scientists, engineers, educators, statisticians, surveyors, metallurgists, astronomers, bankers, merchants, designers — all can be freed from the confusion of machine language and the tedium of paper and pencil arithmetic to spend their valuable time on more creative processes.

ANALYTICAL INSTRUMENTATION SYSTEMS

Application requiring control and readout of analytical instruments may frequently be handled by a modern programmable calculator instead of a high cost mini-computer. The laboratory may already own (or plan to buy) a scientific calculator for individual desk use, and would like to avoid the purchase of a larger, faster machine unless the application really requires it.

A good example of an application that can be handled by a programmable calculator is the Gas Chromatograph/Mass Spectrometer (GC/MS). This type of instrumentation system has been successfully controlled and monitored by a mini-computer, is relatively low speed, and therefore well suited to calculator control.

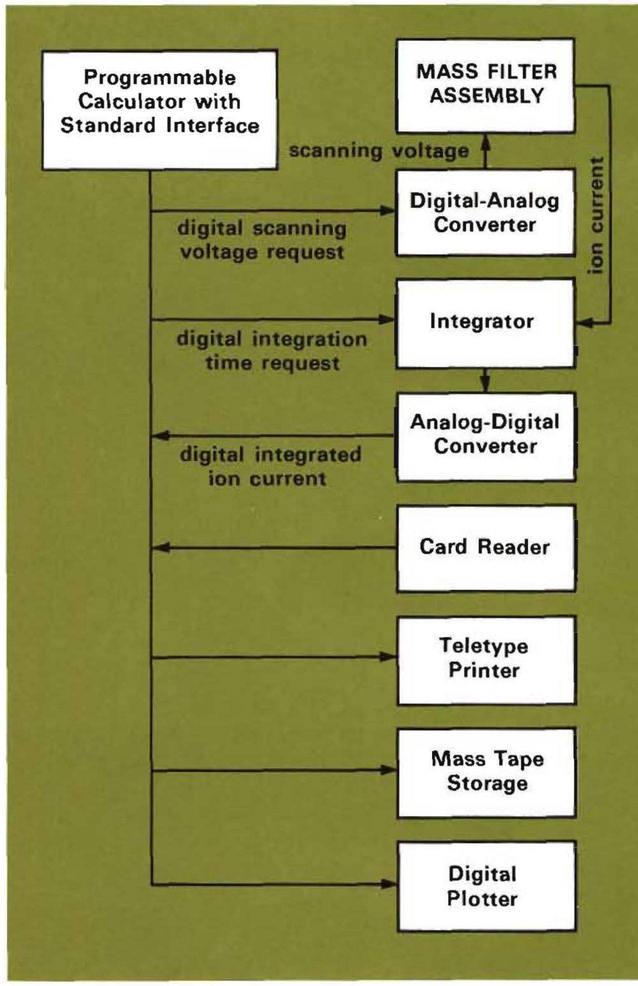
The heart of the GC/MS is a mass filter assembly. Gas samples for mass analysis are inserted into the ionizing chamber and forced through the filter by accelerating electrodes.

The mass of any ions that successfully pass through the filter is directly proportional to the applied scanning voltage. Ions passing through are detected by a photo-multiplier whose output current is fed to an integrator.

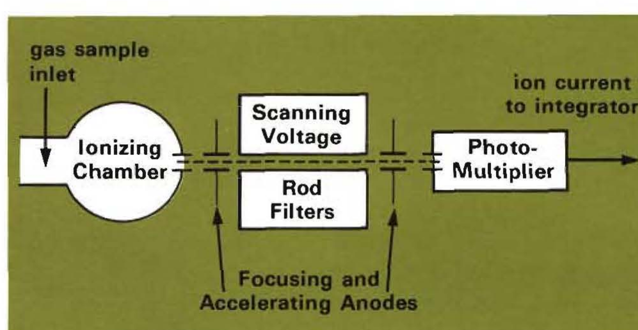
GC/MS operation begins with a calibration cycle program. A reference compound with a few known mass spectrum lines is placed in the inlet. The mass of these known lines can be entered from the keyboard or by punched card. The scanning voltage is then incremented, and at each step the ion current is determined. Signal to noise can be optimized by programming the integration time as a function of signal strength, since the integrated current is divided by the integration time to obtain the actual current.

The scanning voltage of each ion current peak is combined with the known mass of each peak and interpolated to produce a calibration curve which is stored for later use.

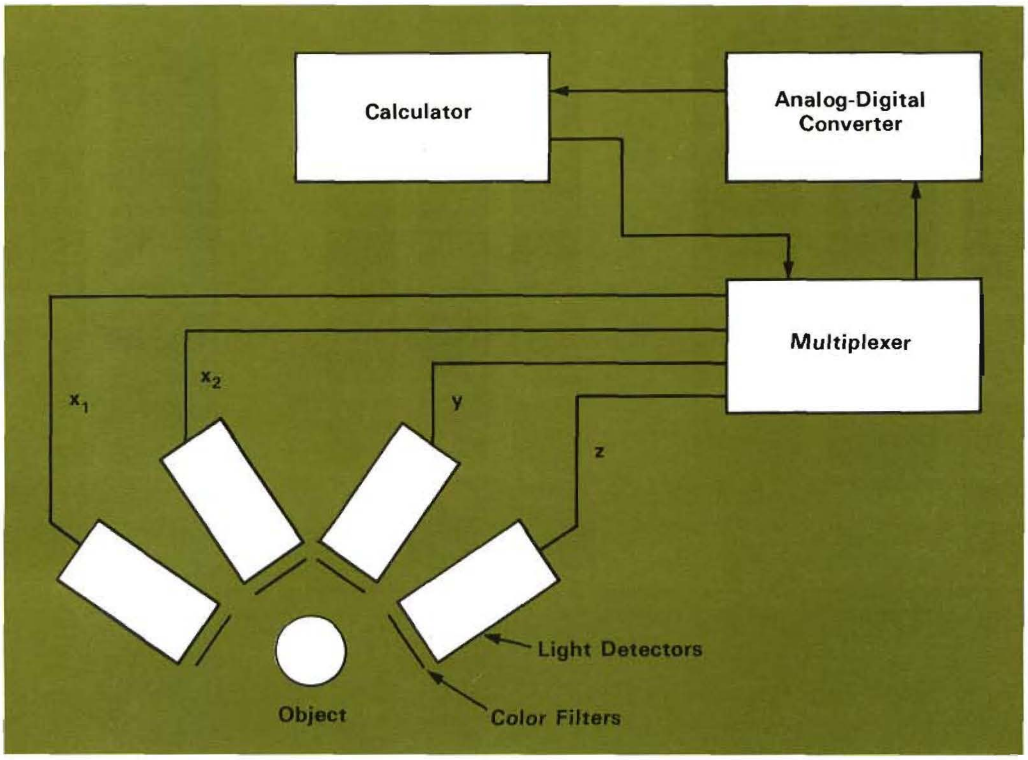
After calibration, the unknown sample is placed in the inlet. The scanning voltage is stepped from the lowest to the highest value required, stopping at each step while the calculator adjusts the integration time for best signal to noise. The resolution (separation of voltage steps) can be constant, or variable, within a scan. Each voltage step is corrected by the calibration curve referred to earlier. The integrated current divided by the integration time gives the amplitude of the mass corresponding to each voltage step. A plotter records the resulting spectrum as it is produced and stored on tape for future use. The voltage and amplitude of each peak can be found mathematically and printed out on a teletype or printer.



Simplified block diagram of a Gas Chromatograph/Mass Spectrometer.



Block diagram of the mass filter assembly of a GC/MS.



Simplified block diagram of a colorimetry system.

COLORIMETRY

Programmable calculators have been successfully applied to the measurement of color. A typical system is illustrated at right. Light from the object being measured passes through color filters which divide it into basic colors. These are measured with photo detectors whose outputs are scanned by a multiplexed analog-to-digital converter and sent to the calculator. The calculator performs the following calculations:

$$x = (x_1 + x_2) \qquad \frac{y}{x+y+z} = K_{00}$$

$$\frac{x}{x+y+z} = K_{01} \qquad \frac{z}{x+y+z} = K_{02}$$

This computes and stores three numbers that uniquely identify the color.

The system referred to has been used to color match mink fur for repair of coats, replacing an experienced "mink matcher" with a calculator and a less experienced technician.

This system could be applied to color matching in process control. More multiplexer stations could be added to monitor the color of material and dyes going into a process, the color of material coming out, and a desired color sample. Using the information and a programmed knowledge of color mixing, the calculator could interface with valves controlling the dye inputs to match the output with the sample.

OTHER CALCULATOR PERIPHERALS

The utility of TEKTRONIX Calculators is enhanced with a family of peripherals including a digital strip printer, X-Y plotter, punched card reader and magnetic tape storage devices.

Dave Takagishi is one of the original 10 people responsible for development of the Scientist 909. He has been involved with design and implementation of the calculator from pre-breadboard through its production phase.

Dave is a graduate of San Jose City College and worked four years with Fairchild Semiconductor before joining Cintra in 1968. He became a Tek man in May, 1971, when Tektronix bought the Cintra assets.

Dave is 31 years old and married. His interests outside of calculators include golf and photography.

the R1340 Data Coupler

Complete testing of today's complex integrated circuits, printed circuit boards and other such products is a formidable task. To accomplish it, an equally formidable array of signal sources, power supplies, test fixtures and measuring devices are brought together to form automatic measurement systems. Some of the more sophisticated systems also include a computer.

How well we accomplish the testing task depends, to a large extent, on the ease with which the various elements of the system "communicate" with each other and with the computer.

The new TEKTRONIX R1340 Data Coupler could be called a "systems communication expert". The coupler is designed to multiplex data inputs and outputs of various system components to a common TTL data bus. This data bus can, in turn, be interfaced to a computer, data receiver, or data source. Using optional interface circuit cards, nearly any form and format of data can be applied to, or acquired from, the R1340. The unit can perform such functions as input/output level conversion, serial-to-parallel and parallel-to-serial format conversion and temporary storage of data in latching registers.

The unit is designed primarily for use with TEKTRONIX Automated Measurement Systems. However, it can serve just as well as an important building block in your system. Here are some of the chores it can perform:

- Provide the interface to bring your system under computer control.
- Couple the system to data-logging equipment.
- Interface the computer to registers, DVMs, test fixtures and other programmable instruments in the system.
- Digitize high-speed waveforms for computer analysis.

The R1340 consists of a rackmount cabinet with power supply, space for twelve plug-in cards and eighteen wired connectors providing a total of 648 input/output lines. Combinations of from one to twelve plug-in cards within the R1340 perform the various functions desired.

The block diagram in Fig. 1 shows four major application areas using the R1340. (Type numbers of TEKTRONIX instruments used in our automated measurement systems are shown in the appropriate blocks.) Although not apparent from the diagram, data logging from a system using the 230 and 240 can be performed through the R1340 without using the computer. Data is logged on computer-compatible magnetic or punched paper tape.

INTERFACE OPTIONS

Since different applications or functions require different interfaces, we should discuss the various interface options available for the R1340 before getting into specific applications. An option consists of a package which includes one or more plug-in circuit cards, interconnecting cables and an instruction manual. Several options (up to a total of 12 cards) can be accommodated in the unit at one time. There are ten options presently available with several more in the design stage. Briefly they are:

1. R1340 to PDP-8/L Computer Interface
2. R1340 to IBM 1800 Computer Interface
3. R1340 to R230/R240 Interface
4. R1340 to Paper Tape Punch/Reader Interface
5. R1340 Data Logging Interface
6. 16-bit Input/16-bit Output Interface
7. 32-bit Input Interface
8. 32-bit Output Interface
9. R568 to R1340 Waveform Digitizing Interface
10. Vertical and Horizontal Signal References Interface.

The waveform digitizing and the signal reference interfaces merit special consideration since they bring new capability to automated testing.

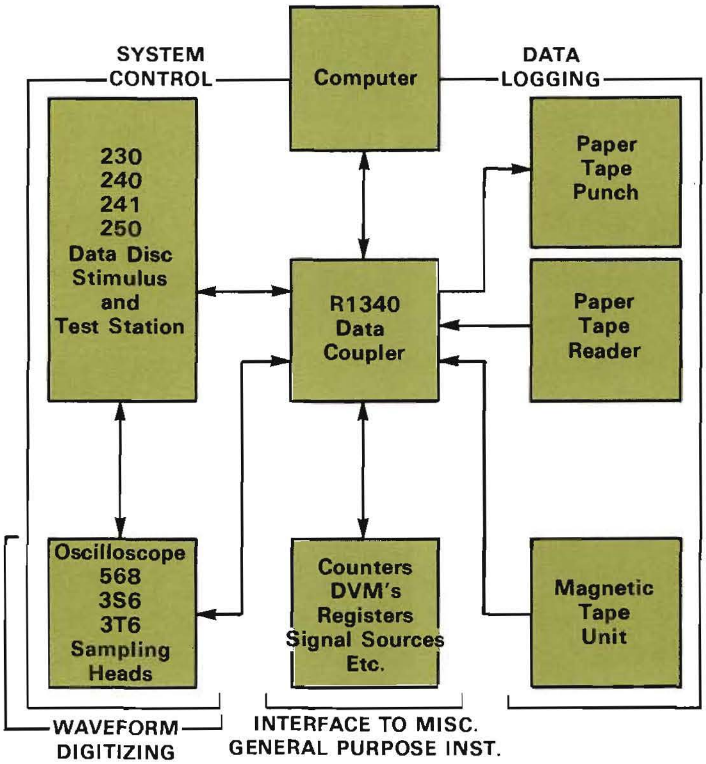


Fig. 1 Four major application areas of the R1340 include system control, data logging, waveform digitizing and interfacing to many general purpose instruments.

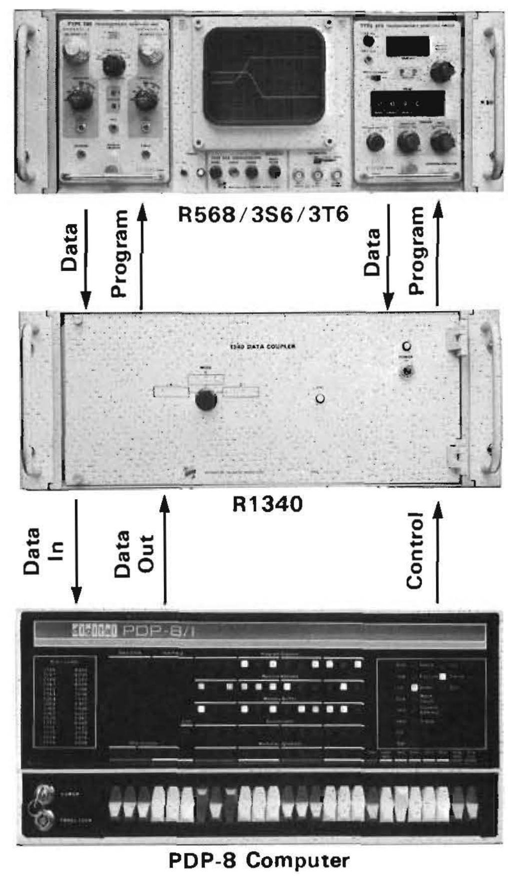


Fig. 2 A basic waveform digitizing system consisting of the R1340 Data Coupler, an R568/3S6/3T6 Oscilloscope and a DEC PDP-8 minicomputer.

WAVEFORM DIGITIZING

Waveform digitizing, as the name implies, is a means of converting an analog waveform into its digital equivalent. A computer can then be used to measure whatever parameters are desired such as risetime, pulse width, period, or delay between two pulses. Smoothing or noise reduction can be performed to improve measurement accuracy or to extract a low-level signal from noise.

A block diagram of the basic waveform digitizing system is shown above. It consists of the R568/3S6/3T6 programmable oscilloscope, the R1340 and a PDP-8 minicomputer. A total of seven interface cards reside in the R1340. Three cards are required to interface the computer to the R1340, two cards program the R568 and plug-ins, and the remaining two cards are the digitizer interfaces.

One of the digitizer interface cards has two, 10-bit A-D converters, buffers and control logic to convert the 3S6 channel A and B analog information to binary numbers. These numbers are then made available to be read by the computer under software control.

The other card consists of a buffered 10-bit D-A converter which outputs an analog voltage to the 3T6 to determine the time position of a particular sample. It, in essence, generates the analog ramp for the sampling sweep unit. Both cards rely on computer-generated operating instructions.

WAVEFORM DIGITIZER LOGIC

Three operating modes are available for the waveform digitizer. One is called the SCAN, SAMPLE and HOLD mode, wherein the horizontal sweep is stepped across the screen in 1023 increments. This is like the normal sampling scope operation with one important difference. The sweep is prevented from going to the next time position until the data in one or both of the A-D buffers has been read by the computer. This enables the memory location itself to be used as a time position pointer for that data word.

The second operating mode is called PARK, SAMPLE and HOLD. In this mode, the self-incrementing operation of the register driving the D-A converter is disabled and now becomes a simple 10-bit latch which will accept a data

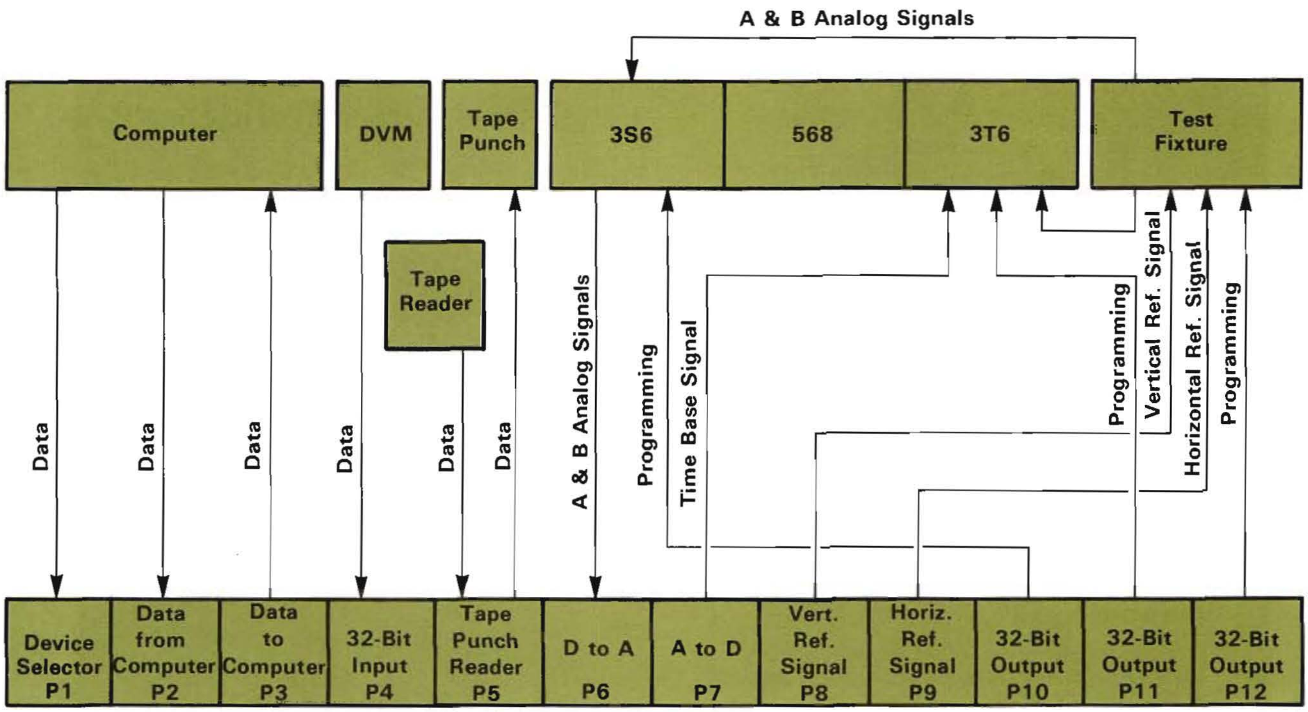


Fig. 3 Block diagram of a computer-controlled system which includes waveform digitizing and vertical and horizontal reference signals.

word from the computer. The sampler now makes samples at any one of 1023 time positions on the waveform being measured. Any number of samples desired may be read at that single time location by the computer. A new word may be loaded into the D-A register at any time to select a new time position or the mode may be changed back to SCAN, SAMPLE and HOLD. Thus, any segment or segments of a waveform may be stored in core, or multiple measurements at single-time locations may be stored for use in noise reduction.

The third operating mode is called SCAN, FREE RUN. Here the sweep D-A operates in the self-increment mode and the logic loop requiring the computer to read the A-D converter before allowing the D-A to move to the next time position, is disabled. This mode is most useful for initial setup of the package since in the SCAN, SAMPLE and HOLD mode, only one sweep can be seen, and in the PARK, SAMPLE and HOLD mode, only a single dot can be seen on screen.

Any of those three modes can be entered via computer, while the SCAN, FREE RUN mode may also be entered by a front panel control on the R1340.

APPLICATION CONSIDERATIONS

Of the two data acquisition modes discussed, the SCAN, SAMPLE and HOLD mode offers the greatest flexibility in the range of measurements that can be made. However, it requires up to 2048 words of computer memory to store a complete sweep of data from channels A and B. Since most standard minicomputers have only 4K of memory, the user would almost certainly have to add storage capacity to accommodate a comprehensive program package.

It should be apparent that a great deal of redundant information is contained in a typical oscilloscope display. This leads to a second type of acquisition routine which uses the PARK, SAMPLE and HOLD mode. It requires somewhat more sophisticated software but has several important advantages over the first method.

Prior to the data acquisition stage, the user specifies the type of measurement and what points must be measured on the waveform. For example, suppose we want to measure risetime, amplitude and channel A to channel B delay. These measurements require 0%, 10%, 50%, 90% and 100% points of the pulses on both channels to be stored.

A 0% zone is established by parking the sweep at the left edge of the screen and then reading the channel A and B samples. Next, the sweep is parked a few tens of increments to the right, samples read and compared with the first ones. A zero slope area is quickly found by stepping the time position around as necessary. Once a suitable time-position is established, several readings of the A-D converters at that one time position are averaged and then stored as the 0% locations for channels A and B. Similarly, to locate the 100% time and amplitude, the time position (sample) is programmed to the right edge of the screen then moved to the left or backward in time. Now the 50% voltage value is calculated and the sampling time position moved around until this value, or something near it, is found. Multiple A-D readings are then made at adjacent time positions with each time location given some average value of these readings. These noise-reduced values are then used to calculate the time position of the "smoothed" 50% crossing. The 10% and 90% points are found in a similar way.

The required parameters of the two vertical channels are stored in only 20 memory locations (10 amplitude and 10 time) compared to 2048 memory locations for storing the complete waveform. Furthermore, the noise level and, hence, repeatability of the measurement have been greatly enhanced, and the whole process carried out with fewer than 100 samples, depending upon the number of samples used for noise reduction purposes.

VERTICAL AND HORIZONTAL SIGNAL REFERENCE INTERFACE

Designed to be used with the Waveform Digitizing Interface, a programmable time standard and programmable voltage standard are available as plug-in cards for the R1340. These standard signals are made available at the system measurement fixture so that all combinations of sampling heads, channel A or B, and 3S6 sensitivity will have a calibration coefficient tabulated in the computer memory. Similarly, a calibration table can be stored for all sweep rates of the 3T6 between 500 ms/div and 1 ns/div. Time and amplitude measurements can thus be made to better than 1% with traceability to NBS.

COMPUTER-CONTROLLED WAVEFORM DIGITIZING SYSTEM

Pictured on the preceding page is a block diagram of a computer-controlled system using the Waveform Digitizer and the Vertical and Horizontal Reference interfaces. The computer has master control over all of the cards in the coupler via Pl, the Device Selector.

The Device Selector takes data from the computer, converts it from a binary number to a selection code and uses it to select one or more cards in the data coupler. The selected card immediately transfers data to or from the interface bus in the R1340. The computer generates a strobe pulse when it sends or receives data.

The Device Selector also receives a signal from each card which indicates the status of that card. When the computer is ready for data from the coupler, it looks for a signal from the Device Selector and then handles the data as the computer program requires.

SOFTWARE

No software is presently available as part of the R1340 except as part of an operating S3150 system, and that software is in a language closely related to the particular hardware in the system.

Existing hardware interfaces used in the R1340 for the DEC PDP-8/L and IBM 1800 computer are well documented and allow machine-language drivers to be easily written. Hardware interfaces for other computers (including the DEC PDP-11) are under development. Special software, a high-level language written in DEC PDP-11, FORTRAN IV, will be available in 1972. The TEKTRONIX programming language being developed for the PDP-11 will allow interactive English-language control of computer peripherals and test instruments interfaced through the R1340. Digitized waveform data acquired by the Waveform Digitizing Interface can be computer processed through measurement routines for determining such parametric data as risetime, pulsewidth, etc. Measurement routines may be interactively altered or extended for unusual applications by writing FORTRAN routines to perform special functions. Arithmetic, data-logging, instrument programming and display operations are to be included.

CONCLUSION

The R1340 Data Coupler greatly expands system flexibility with or without the use of a computer. Through waveform digitizing and accurate voltage and timing references it brings new measurement capability to dynamic testing. Your TEKTRONIX field engineer can help you apply the R1340 to solving your measurement problems.

Tektronix, Inc.

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ANNOUNCING PRICE REDUCTIONS for TEKTRONIX DESK-TOP CALCULATORS

Tektronix, Inc. is replacing its Scientist 909 Calculator with a lower cost, higher performance version. The original 909, priced at $3780, had 85 program steps and 26 storage registers. Its replacement, priced at $3200, has 256 program steps and 26 storage registers and is warranted for a full year. Price reduction was achieved through increased use of MOS/LSI chips and new manufacturing techniques. A similar increase in performance and decrease in price is available in the Statistician 911 Calculator.

All of the popular operating features and performance characteristics of the earlier model 909 are retained. The mathematical keyboard, which contains programmable keys for trigonometric and hyperbolic functions plus inverse trig and hyper functions, is standard at no extra cost.

The math oriented keyboard also contains one-key functions for logarithms, raising any number to any power over a dynamic range of ±10 digit mantissa times $10^{\pm 99}$, a square root of the sum of the square key, and keys which provide unlimited nesting. These and other unique keys, plus the machine's ability to observe mathematical hierarchy, make the TEKTRONIX Calculator easy to use. Even more significant is the calculator's power to solve complex mathematical problems involving as many as 5120 steps when used with the optional 926 Programmer.

The operator never has to learn a machine language or develop techniques for circumventing nonprogrammable keys which are often found on other machines. Some of the reasons are: The TEKTRONIX Calculator speaks the universal language of mathematics, all keys are programmable, and less programming effort is required than with machines with thumbwheels, toggle switches or key notations.

Availability: Stock

Tektronix, Inc.
Calculator Products Division

8/71

TEKTRONIX®

NEW PRODUCTS

SEPTEMBER 1971

SUPPLEMENT NO. 2 to the MARCH '71 CATALOG

This is the second in the series of New Product Supplements designed to keep you up to date on products introduced by Tektronix, Inc. It supplements your TEKTRONIX March 1971 catalog and should be filed with it. Most of the products included in this supplement were introduced at WESCON and are available for demonstration by your local field engineer.

7000-SERIES PRODUCTS

7L12

The 7L12 Spectrum Analyzer is a swept front-end analyzer in plug-in form, covering 1 MHz to 1.8 GHz. Dynamic range is greater than 70 dB with intermodulation distortion less than 70 dB. An amplitude and frequency calibrator is provided. Resolution bandwidth is selectable 300 Hz to 3 MHz in decade steps with a shape factor of 4:1 (60 dB to 6 dB). All display parameters are calibrated and quantitative information is displayed on both front panel and CRT readout. CRT readout is one of the unique 7L12 features. The multiple plug-in concept of the 7000-Series allows simultaneous display of both frequency and time-domain data. Much effort has gone into human engineering to make the 7L12 easier to use and to reduce the chance of human error.

7L12 Spectrum Analyzer.............................. $4850

7CT1N

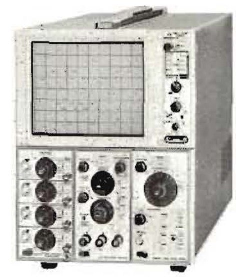
The 7CT1N Curve Tracer is a plug-in unit used in TEKTRONIX 7000-Series Oscilloscope Systems for displaying characteristic curves of small-signal semiconductor devices to power levels up to 0.5 watts.

A variable collector/drain sweep produces a maximum peak voltage of at least 250 volts; a base/gate step generator produces up to 10 calibrated current or voltage steps. Ranges of step amplitudes are 1 μA/step to 1 mA/step for current and 1 mV/step to 1 V/step for voltage. In addition the unit has a vertical display amplifier with deflection factors ranging from 10 nA/div to 20 mA/div and a horizontal amplifier output compatible with other 7000-Series Plug-ins.

7CT1N Curve Tracer.................................. $400

For further information or a demonstration of these products, please contact your local TEKTRONIX Field Office or return the enclosed inquiry card.

5100-SERIES PRODUCTS



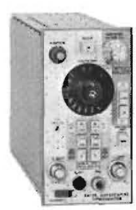
5103N/D15

The 5103N/D15 Storage Oscilloscope features a single beam, 6½ inch 8 x 10 div (½ in/div) CRT with bistable, split-screen storage and an internal graticule. 5103N/D15 storage writing speed is at least 200 div/ms in the normal mode and 800 div/ms in the enhanced mode. Accelerating potential is 3.5 kV and the phosphor is similar to P1.

Storage time is at least one hour at normal intensity, increasing to ten hours at reduced intensity. View time is at least one hour at normal intensity. Erase time is approx 250 ms.

5103N/D15 Storage Oscilloscope (without plug-ins)......... $1095

R5103N/D15 Storage Oscilloscope (without plug-ins)........ $1095



5A13N

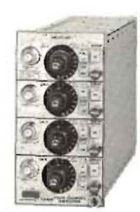
The 5A13N Differential Comparator is a plug-in amplifier for all 5100-Series Oscilloscope systems. It incorporates a number of performance features which make it particularly versatile, especially for measurements in difficult low-amplitude, low-frequency areas. The following three operational areas describe the functions of the 5A13N.

As a conventional amplifier the 5A13N has DC-to-2 MHz or 10 kHz bandwidth over the 1 mV/div to 5 V/div deflection factor range.

As a differential amplifier it maintains its conventional features and provides a balanced input for applications requiring rejection of a common-mode signal. The CMRR is 10,000:1 from DC to 20 kHz, decreasing to 100:1 at 2 MHz.

The 5A13N may be used to apply a signal of up to $\pm$10 volts to either input with the deflection factor set at 1 mV/div. The signal may then be viewed in 10,000 1-mV increments by offsetting the signal with the opposing comparison voltage.

5A13N Differential Comparator.......................... $550



5A14N

The 5A14N Four Trace Amplifier is a solid-state amplifier for use in the 5103N Oscilloscope. Four identical channels with simplified controls have deflection factors from 1 mV/div to 5 V/div, with bandwidth at least 2 MHz at all deflection factors. The 5A14N may be used in any combination with any other 5100-Series Plug-in for displaying up to eight traces. For instance, two 5A14N Amplifiers

U.S. Sales Prices FOB Beaverton, Oregon

provide eight traces; one each 5A14N and 5A15N Amplifiers provide five traces. Each amplifier may be used in the 5103N horizontal plug-in compartment for X-Y operation.

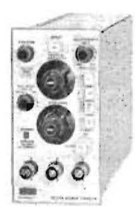
5A14N operating modes are each channel separately, and alternate or chop between any combination of channels. Internal trigger is available from channel one only or from each displayed trace.

5A14N Four Trace Amplifier $575


5A22N

The 5A22N Differential Comparator is a differential amplifier for use with all 5100-Series Oscilloscope Systems. Significant performance features are 10 μV/div to 5 V/div deflection factors, DC-to-1 MHz bandwidth, selectable HF and LF −3 dB points, common-mode rejection ratio of 100,000:1 at 10 μV/div DC coupled, and a DC offset feature with ±0.5 V range from 10 μV/div to 50 mV/div and ±50 V range from 100 mV/div to 5 V/div.

5A22N Differential Amplifier $425

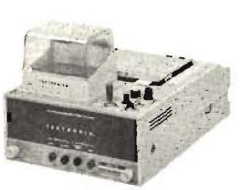

5CT1N

The 5CT1N Curve Tracer is a plug-in unit used in TEKTRONIX 5100-Series Oscilloscope Systems for displaying characteristic curves of small-signal semiconductor devices to power levels up to 0.5 watts.

A variable collector/drain sweep produces a maximum peak voltage of at least 250 volts; a base/gate step generator produces up to 10 calibrated current or voltage steps. Ranges of step amplitudes are 1 μA/step to 1 mA/step for current and 1 mV/step to 1 V/step for voltage. In addition, the unit has a vertical display amplifier with deflection factors ranging from 10 nA/div to 20 mA/div and a horizontal amplifier output compatible with other 5100-Series Plug-ins.

5CT1N Curve Tracer $350

576 CURVE TRACER TEST FIXTURE


172

The 172 Programmable Test Fixture, when used with the TEKTRONIX 576 Curve Tracer, permits the operator to program up to eleven sequential tests on FETs, transistors and diodes. This fixture saves measurement time in applications where a series of tests are to be made on a number of devices. To make the same tests without this fixture requires manual setting of the 576 controls for each particular test. This process is repeated for each test. The programmable fixture sequences through as many as eleven different tests on each device without readjusting panel controls and while the device remains in the test socket.

The 172 sequences through the various tests either automatically or manually. A variable RATE control is provided for the operator to set the test sequence at a rate which is best for him. A new operator requires more time per test, but with experience he will want to test at a faster rate. A front-panel switch or an optional foot switch advances the test in the manual mode.

Programming is straightforward. Inserting plastic pins in holes in the programming card sets individual test conditions. Omit the pin from a particular test hole and the 172 skips that test. After installing the program pins in the card, the card is put into the card reader portion of the 172 and the operator starts the test sequence.

172 Programmable Test Fixture $1400

PORTABLE TDR SYSTEM


1501

The 1501 Time Domain Reflectometer (TDR) is a portable, battery-operated system, used to detect and locate faults and to measure impedance variations in transmission cables out to 10,000 feet through the use of test pulses. Resultant reflections from any discontinuities indicate the seriousness and character of the faults.

The 1501 is especially designed for use with a 323 battery-powered oscilloscope, but other oscilloscopes can be used. The 1501 can be used without an oscilloscope if a strip chart recorder is plugged into a center compartment in the 1501. Each strip chart recording is four centimeters wide by sixty centimeters long to allow permanent, inexpensive, high-resolution TDR plots of entire cables, or any particular portion of a cable.

The chart recorder in the 1501 can also be driven by the 1401A or 1401A-1 Spectrum Analyzer.

1501 Time Domain Reflectometer (with recorder) $1900

1501, Option 1 (without recorder) $1425

PROBES

The P6056 Probe is a miniature 10X attenuation, low-capacitance probe for use with 50 Ω, wide-band oscilloscopes. Bandwidth DC to 3.5 GHz. This probe can also be used with 50 Ω sampling systems, such as the 3S1 plug-in, or the S1 and S2 sampling heads, with a BNC male to GR adapter (017-0063-00). The probe is equipped with a special BNC connector that provides trace identification and CRT readout information when used with plug-in units and mainframes that have these features.

The P6057 Probe is a miniature 100X attenuation probe with a bandwidth of DC to 1.7 GHz that has all other features of the P6056 probe, including the 6-ft and 9-ft probe length.

P6056 Probe $45

P6057 Probe $45

U.S. Sales Prices FOB Beaverton, Oregon

For further information or a demonstration of these products, please contact your local TEKTRONIX Field Office or return the enclosed inquiry card.

INFORMATION DISPLAY PRODUCTS


603

The 603 Storage Monitor is a compact half-rack width display monitor with 2-MHz bandwidth X-Y amplifiers. Vertical rackmount space required is only 5¼ inches. Two 603s rackmounted side-by-side fit into a standard rack width.

True differential, 1 MΩ input, X and Y amplifiers have less than 1° phase difference to 500 kHz. The 5 MHz Z-axis is DC-coupled.

The 603 provides stored displays of alphanumeric and graphic information from computers and other data-transmission systems. Viewing time is at least one hour and may be extended to ten hours. Fast information-storage rate of at least 200,000 dots per second qualifies it well for computer-processed data display. The TEKTRONIX-developed bistable storage CRT used in the 603 eliminates the need of costly memory devices for refreshing the information display.

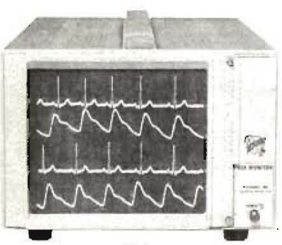
The 603's relatively large (6½-inch) storage CRT in a small package meets the display size and mechanical space requirements of system designers. The 603 Storage Monitor is well suited for many display applications in ultrasonic detection systems, electron microscope systems, radiation and thermal scanning systems, speech therapy, mechanical pressure, volume and vibration analysis, medical and biophysical systems.

The 603 has a Variable Brightness control which adds new versatility to the bistable storage tube.

Operating functions are remotely programmable through contacts at the remote-program connector on the rear panel. X-Y-Z differential inputs are provided through rear BNC connectors. X-Y-Z inputs are also available at the remote-program connector.

A unique option offers an internal time base with six decade-range sweep rates from 1 μs to 0.1 s. Triggering is by internal source, + and − slope, DC-coupled.

603 Storage Monitor **$1100**


604

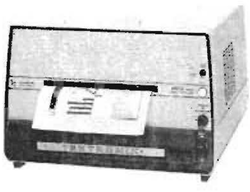
The 604 Display Monitor is a compact, half-rack width, bright 6½ inch CRT monitor requiring only 5¼-inch vertical rackmount space. Two 604s rackmounted side-by-side can fit into a standard rack width.

True differential, 1 MΩ input, 2-MHz bandwidth X and Y amplifiers have less than 1° phase difference to 500 kHz. The 5 MHz Z-axis is DC-coupled.

The 604's relatively large (6½-inch) CRT with 8 x 10 div (½ in/div) in a small package ideally meets the display and space requirements of system designers in applications such as pulse height analysis, infrared detection, data-communication systems testing, component and logic testing, vibration analysis and medical instrumentation. The 604 is well suited for many other applications including: phase shifts and frequency ratios using Lissajous figures, raster displays with intensity modulation and apparent dynamic three-dimensional illustrations that change size and shape. Visual display of computer-processed data enhances understanding of the processed information and improves ease and time of analyzing the results.

A unique option offers an internal time base with six decade-range sweep rates from 1 μs to 0.1 s. Triggering is by internal source, + and − slope, DC-coupled.

604 Display Monitor **$700**


4602

The 4602 Video Hard Copy Unit provides permanent facsimile copy from static television signals. Composite television picture video is applied to a loop-through input connection on the 4602 rear panel. The TV signal is copied by the 4602 providing an accurate gray scale representation of the television inputs. High contrast copies of alphanumeric and graphic displays are also furnished using the 4602.

Installation consists merely of connection to the power line and to the video information to be copied since the 4602 is completely self-contained. Front-panel controls allow the user to standardize and copy video signals in the range of 0.2 V p-p to 3 V p-p. Copy command is initiated by pressing a front-panel control, or by supplying an external command. Contrast and Density are adjusted by the operator with simple-to-use front-panel controls.

Easy-to-handle 8½ x 11-inch dry copies are convenient for communication, documentation, recording and filing uses in unlimited applications, a few of which are: education, banking and finance, law enforcement, refreshed video terminals, legal, medical and industrial firms.

Composite television picture video is applied to a loop-through input connection on the 4602 rear panel. Internal synchronization is derived from the composite video signal. Video information is required to be unvarying during a brief sampling period (about 20 seconds). An additional 20 seconds is required to process the hard copy.

3M Brand Type 777 Dry-Silver Paper provides the high image contrast required for high-resolution copies of complex graphics and alphanumerics. It offers the user the stability normally associated with wet-process photosensitive paper, plus the convenience of dry printout papers. Cost is low: 5 to 8 cents per 8½ by 11 inch copy, depending on usage. Roll size is 8½ inches by 500 feet.

4602 Video Hard Copy Unit **$3750**

For further information or a demonstration of these products, please contact your local TEKTRONIX Field Office or return the enclosed inquiry card.

U.S. Sales Prices FOB Beaverton, Oregon

AUTOMATED TESTING SYSTEMS

The S-3160 LSI/MOS Test System performs parametric, functional and dynamic tests on all types of MOS and bipolar shift registers, random-access memories, read-only memories and complex logic arrays. The system configuration includes a two-bay rack, a separate Graphic Display Terminal and Test Station(s).

Devices with up to 64 pins may be tested with combined input-output electronics. Devices with up to 128 pins may be tested by splitting the input-output connections.

FUNCTIONAL TESTS are conducted with a high-speed driver and dual, strobed comparators for each pin. A four-phase clock serves four selected pins. Clock-cycle repetition rate is 500 Hz to 20 MHz (two ranges). Clock transitions are independently programmed in 5-ns increments. Comparator and data strobes are positioned throughout the clock-cycle in 1-ns increments.

A 20-MHz shift register at each pin stores data patterns and address sequences for input forcing, as well as mask and expected data patterns for output comparison. Direct output data or errors may be stored on-the-fly for subsequent analysis or display. 1024 bits per pin may be recirculated or chained at adjacent pins for greater pattern length. Mode change micro-instructions issue directly from computer memory during run time.

DYNAMIC TESTS including risetime, propagation delay and access time are performed in a separate subsystem. There are five time ranges, ± 100 ns to ± 1 ms, with 100-ps resolution and 1% accuracy. Dynamic test rates are up to 250 per second.

PARAMETRIC (DC) TESTS such as stress, leakage, breakdown, resistance, I_{out}, V_{out}, I_{in}, and V_{in} are performed in a separate parametric test subsystem. Measurements can also be made with forcing function and dual, strobed comparators at each pin. The DUT may be functionally initialized with programmable clock, data and strobe signals and dc stimuli. Parametric test rates are up to 250 per second.

The S-3160 is controlled by a Digital Equipment Corporation PDP-11 with 16-bit word length. Memory includes an 8K core and a 65K disc.

Software includes pattern generator, translator/editor and executive programs. A procedure-oriented, interactive English-language source is used. An English-language executive is used for test-sequence control.

Auto-handlers, manual insertion, environmental handlers, wafer probers or EC-board test stations are all served by the same test circuitry.

THE FOLLOWING PRODUCTS WERE INCLUDED IN THE JULY 1971 NEW PRODUCT SUPPLEMENT

7904 500-MHz Oscilloscope System

432 25-MHz Portable Oscilloscope

434 25-MHz Portable Storage Oscilloscope

453A-1,-2,-3,-4 60-MHz Portable Oscilloscopes

1401A/1401A-1 Portable Spectrum Analyzers

147 NTSC Test Signal Generator

148 EBU Insertion Test Signal Generator

630 Monochrome Picture Monitor

650 Color Picture Monitor

2620 Stimulus Isolator

26A2 Differential Amplifier

C-5 Camera

C-59 Camera

Writing Speed Enhancer

P6060/P6061 Probes

Calculators

1711 Machine Control Unit

1791 NC Program Verifier

4002A Graphic Computer Terminal

For further information or a demonstration of these products, please contact your local TEKTRONIX Field Office or return the enclosed inquiry card.

Tektronix, Inc.

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Cable: TEKTRONIX · OVERSEAS DISTRIBUTORS IN OVER 30 COUNTRIES
TEKTRONIX FIELD OFFICES in principal cities throughout the world. Consult Telephone Directory

Tektronix, Inc.

Revised Price List

Effective July 12, 1971

These prices supersede all other published prices including those currently appearing in advertisements, catalogs, booklets, and all other literature.

OSCILLOSCOPES

Type	Price
310A	$1050
317	1250
RM17	1325
321A	1250
323	1050
324	1225
360	450
410	1025
410 MOD 950A	975
410 MOD 950B	985
422	1600
422 MOD 125B	1850
422 MOD 146B	1575
R422	1675
R422 MOD 150B	3250
432	1585
R432	1625
434	2150
R434	2190
453A	2050
453A MOD 127C	2135
453A MOD 163D	2150
R453A	2135
R453A MOD 127C	2220
R453A MOD 163D	2235
453A-1	1850
453A-2	1875
453A-3	1900
453A-4	1700
454A	3200
454A MOD 163D	3300
R454A	3285
R454A MOD 163D	3385
502A	1485
RM502A	1750
503	850
RM503	865
RM503 MOD 171A	915
504	735
RM504	750
RM504 MOD 171A	800
507	4300
515A	1400
RM15	1475
516	1750
519	5200
520	2825
R520	2850
521	2825
R521	2850
522	3075
R522	3100
528	1000
528 MOD 146B	975
528 MOD 147B	1030
528 MOD 188G	1000
529	1560
529 MOD 147B	1590
529 MOD 188D	1970
RM529	1575
RM529 MOD 188D	1990
531A*	1500
533A*	1650
535A*	2050
RM35A*	2200
536*	1850
543B*	1950
RM543B*	2050
544*	2025
RM544*	2175
545B*	2100
RM545B*	2200
546*	2350
RM546*	2450

Type	Price
547*	$2350
RM547*	2450
549*	2700
551*	2750
556*	4100
R556*	4200
561B*	695
R561B*	745
R561B MOD 171A*	795
564B*	1195
564B MOD 08*	1195
564B MOD 121N*	1350
564B MOD 08, 121N*	1350
R564B*	1245
R564B MOD 08*	1245
R564B MOD 121N*	1400
R564B MOD 08, 121N*	1400
R564B MOD 171A*	1295
R564B MOD 08, 171A*	1295
R564B MOD 121N, 171A*	1450
R564B MOD 08, 121N, 171A*	1450
565*	2100
RM565*	2200
567*	1050
RM567*	1150
568*	1250
R568*	1300
575	1500
575 MOD 122C	1800
576	2800
576 MOD 301W	2300
581A*	2050
585A*	2600
RM585A*	2700
647A*	1925
R647A*	2050
5030	1850
R5030	1850
R5030 OPTION 4	1850
5031	2500
R5031	2500
R5031 OPTION 4	2500
5103N*	220
5103N OPTION 1*	220
5103N/D10*	540
5103N/D10 OPTION 1*	540
R5103N/D10*	540
R5103N/D10 OPTION 1*	540
5103N/D11*	1020
5103N/D11 OPTION 1*	1020
R5103N/D11*	1020
R5103N/D11 OPTION 1*	1020
5103N/D12*	870
5103N/D12 OPTION 1*	870
R5103N/D12*	870
R5103N/D12 OPTION 1*	870
5103N/D13*	1370
5103N/D13 OPTION 1*	1370
R5103N/D13*	1370
R5103N/D13 OPTION 1*	1370
D10	320
D11	800
D12	650
D13	1150
7403N*	950
R7403N*	1050
R7403N OPTION 5*	1100
7503*	1875
7503 OPTION 1*	1475
7503 OPTION 3*	1950
7504*	2100
7504 OPTION 1*	1700
7504 OPTION 2*	2175
7504 OPTION 3*	2175

Type	Price
7514*	$3500
7514 OPTION 1*	3100
7514 OPTION 2*	3575
7514 OPTION 3*	3575
7704*	2550
7704 OPTION 1*	2150
7704 OPTION 2*	2625
7704 OPTION 3*	2625
R7704*	2650
R7704 OPTION 1*	2250
R7704 OPTION 2*	2725
R7704 OPTION 3*	2725
R7704 MOD 101K*	2700
R7704 OPTION 1*	2300
R7704 OPTION 2*	2775
R7704 OPTION 3*	2775
7904*	2900
7904 OPTION 1*	2500
7904 OPTION 2*	2975
7904 OPTION 3*	2975
7904 OPTION 4*	3250

PLUG-IN UNITS

Type	Price
CA	450
L	375
M	825
O	825
Q	600
T	450
W	800
1A1	725
1A2	460
1A4	1150
1A5	750
1A6	400
1A7A	575
1S1	1400
1S2	1525
2A60	200
2A63	275
2B67	300
2B67 MOD 730A	450
3A2	800
3A3	950
3A5	1350
3A6	600
3A7	750
3A8	875
3A9	600
3A10	800
3A72	450
3A74	900
3A74 MOD 730A	950
3A75	285
3B2	950
3B3	680
3B4	495
3B5	1440
3C66	650
3S1	1400
3S2*	1000
3S5*	2100
3S6*	2100
S1	375
S2	430
S3A	580
S4	875
S5	375
S6	875
S50	525
S51	500
S52	550
S53	425
S54	325
3S7	575
3T2	1400
3T5	$2100
3T6	2100
3T7	620
3T7 MOD 950A	620
3T77A	1000
5A15N	115
5A18N	265
5A20N	165
5A21N	185
5A23N	65
5A24N	25
5B10N	175
5B12N	450
5B13N	85
6R1A	3800
7A11	950
7A12	900
7A13	1250
7A14	700
7A15	270
7A16	625
7A18	535
7A18 OPTION 1	500
7A19	500
7A19 OPTION 1	700
7A22	575
7B50	450
7B51	575
7B52	950
7B53N	750
7B70	625
7B71	725
7B92	1400
7D13	560
7D13 OPTION 1	495
7D14	1400
7M11	325
7S11*	575
7S12*	1200
7S12 OPTION 1*	1200
7T11	1625
10A1	1125
10A2A	985
11B1	800
11B2A	1070
81A	230
82	1000
86	600

CALCULATOR PRODUCTS

Type	Price
905	75
909	3200
909 OPTION 3	3700
911	3200
911 OPTION 3	3700
920	150
923	600
926	1495
928	245
941	995

MACHINE CONTROLS

Type	Price
1701	9750
1701 OPTION 5	10,600
1701 OPTION 9	10,050
1701 OPTION 10	10,250
1702	11,000
1702 OPTION 5	11,850
1702 OPTION 9	11,300
1702 OPTION 10	11,500
1704	11,500
1704 OPTION 5	12,350
1704 OPTION 9	11,800
1704 OPTION 10	12,000
1711	5300
1791	11,500

*Prices do not include plug-in units.

Second Printing 8/71

INFORMATION DISPLAY PRODUCTS

Type	Price
601	$1400
601 MOD 146B	1375
602	950
602 MOD 146B	925
602 MOD 174K	950
611	3175
611 MOD 162C	3175
630	1050
630 MOD 08	1050
650	2500
4002A	8800
4002A OPTION 1	8820
4002A OPTION 2	8950
4002A OPTION 3	9100
4002A-1	8400
4002A-1 OPTION 1	8420
4002A-1 OPTION 2	8550
4002A-1 OPTION 3	8700
Interface Units for 4002A & 4002A-1	600-750
T4005	7850
Interface for T4005 & 4201	850
4201	4950
4501	3175
R4501	3175
4551	1800
4601	3750
4601 OPTION 1	3750
4601 OPTION 2	3750
4601 OPTION 3	3750
4701	1500
R4701	1525
4901	525
4902	750
4951	300

MEASUREMENT SYSTEMS

Type	Price
S3110	15,500
S3110 Model 651A	16,350
S3111	17,500
S3111 Model 651A	18,350
S3120	36,850
S3121	28,850
S3122	35,500
S3130	53,500
S3131	45,150
S3132	51,750
S3150	140,000
S3150 Model 651B	100,000

SPECTRUM ANALYZERS

Type	Price
1L5	1300
1L10	1400
1L20	2550
1L40	2550
3L5	1400
3L10	1500
491	4895
491 MOD 139L	3500
491 MOD 139M	3700
R491	4995
R491 MOD 139L	3600
R491 MOD 139M	3800
1401A	2400
1401A-1	2450
1401A/323	3450
1401A/324	3625
1401A-1/323	3500
1401A-1/324	3675

AUXILIARY INSTRUMENTS

Type	Price
106	750
106 MOD 146B	725
109	550
111	500
113	350
114	350
114 MOD 146B	325
115	1075
115 MOD 146B	1050
R116	2100
R116 MOD 703L	$3365
122	230
FM122, RM122	235
125	400
FM125, RM125	405
127	1125
129	1100
130	350
132	650
134	225
140, R140	2150
141A, R141A	2150
141A MOD 703Z	2335
R141A MOD 703Z	2335
142, R142	2350
144, R144	2500
146, R146	2500
147, R147	2900
160A	300
161	225
162	225
163	225
175	2125
176	1600
184	760
191	695
191 MOD 146B	670
230	4100
R230	4150
240	4850
R240	4900
241	2800
R241	2850
R250, R250 MOD 29	1800
262	2125
263	450
281	95
282	95
282 MOD 125D	100
284	700
284 MOD 146B	675
285	225
286	825
287	850
R287	900
R288	1200
R293	1600
R293 MOD 703M	1875
1101	300
R1140	5000
R1140 MOD 950A	6125
R1340	3000
R1340 MOD 950A	4800
1501	1900
1501 OPTION 1	1425
2101	800
2601*	495
2601 OPTION 1*	450
R2601*	495
R2601 OPTION 1*	450
26A1	280
26A2	550
26G1	430
26G2	300
26G3	485
2620	450
2901	740

SCOPE-MOBILE® CARTS

Type	Price
200-1	120
200-2	120
201-1	165
201-2	185
202-1	165
202-1 MOD 52	250
202-2	185
203-2 (Formerly 201-3)	155
204-2	225
204-3	195
205-1	190
205-2	210
205-3	210
206-1	90

CAMERAS

Type	Price
C-5	$185
C-10	450
C-12	590
C-12-E	860
C-12-N	505
C-12-NE	775
C-12-R	625
C-12-RE	895
C-12-547	610
C-12-547 E	880
C-12-547 N	525
C-12-547 NE	795
C-12-547 R	645
C-12-547 RE	915
C-12-549	630
C-12-549 E	900
C-12-549 N	545
C-12-549 NE	815
C-12-549 R	665
C-12-549 RE	935
C-12-608	795
C-12-608 E	1065
C-12-608 N	710
C-12-608 NE	980
C-12-608 R	830
C-12-608 RE	1100
C-12-662	770
C-12-662 E	1040
C-12-662 N	685
C-12-662 NE	955
C-12-662 R	805
C-12-662 RE	1075
C-27	590
C-27-E	860
C-27-N	505
C-27-NE	775
C-27-R	625
C-27-RE	895
C-27-547	610
C-27-547 E	880
C-27-547 N	525
C-27-547 NE	795
C-27-547 R	645
C-27-547 RE	915
C-27-549	630
C-27-549 E	900
C-27-549 N	545
C-27-549 NE	815
C-27-549 R	665
C-27-549 RE	935
C-27-608	795
C-27-608 E	1065
C-27-608 N	710
C-27-608 NE	980
C-27-608 R	830
C-27-608 RE	1100
C-27-662	770
C-27-662 E	1040
C-27-662 N	685
C-27-662 NE	955
C-27-662 R	805
C-27-662 RE	1075
C-30A-G	490
C-30A-GE	760
C-30A-N	440
C-30A-P	525
C-30A-PE	795
C-30A-R	560
C-30A-RE	830
C-31-G	605
C-31-GE	875
C-31-N	555
C-31-P	640
C-31-PE	910
C-31-R	675
C-31-RE	945
C-32-G	680
C-32-GE	950
C-32-N	630
C-32-P	715
C-32-PE	985
C-32-R	750
C-32-RE	1020
C-50-G	$715
C-50-N	665
C-50-P	750
C-50-R	785
C-51-G	1015
C-51-N	965
C-51-P	1050
C-51-R	1085
C-52-G	1065
C-52-N	1015
C-52-P	1100
C-52-R	1135
C-59-G	415
C-59-N	365
C-59-P	450
C-59-R	485
C-70-G	815
C-70-N	765
C-70-P	850
C-70-R	885

PROBES†

Type	Price
P6006	31
P6007	35
P6008	50
Environmentalized	80
P6009	66
P6011	25
P6012	40
P6013A	200
P6015	275
P6027	20
P6028	20
P6034	50
P6035	50
P6045	325
Power Supply	125
Probe w/Power Supply	450
P6046	470
Amplifier	380
Probe & Amp	850
P6048	65
P6051	375
P6052	55
P6053	55
P6054	50
P6055	75
P6060	35
P6061	38
P6021	
w/Passive Termination	129
without/Passive Termination	98
Passive Termination	37
w/Type 134 Amp & Pwr. Supply	352
Type 134 Amplifier only	225
Power Supply only	40
P6022	
w/Passive Termination	170
without/Passive Termination	127
Passive Termination	49
w/Type 134 Amp. & Power Supply	383
P6040	20
CT-1 Current XMFR	30
P6040/CT-1 Current Probe	50
P6041	20
CT-2 Current XMFR	35
P6041/CT-2 Current Probe	55
CT-5	450
P6042	725

ACCESSORIES

Type	Price
015-0108-00	230
015-0126-00	1000
020-0031-00	525
122-0603-00	120
122-0754-00	120
122-0929-00	120

†Probe prices apply to all cataloged variations of each probe, except the P6008 as noted.

TEKNIQUE:

THE 7D14 COUNTS CURRENT TO MINIMIZE CIRCUIT LOADING

by Emory Harry, Field Engineer

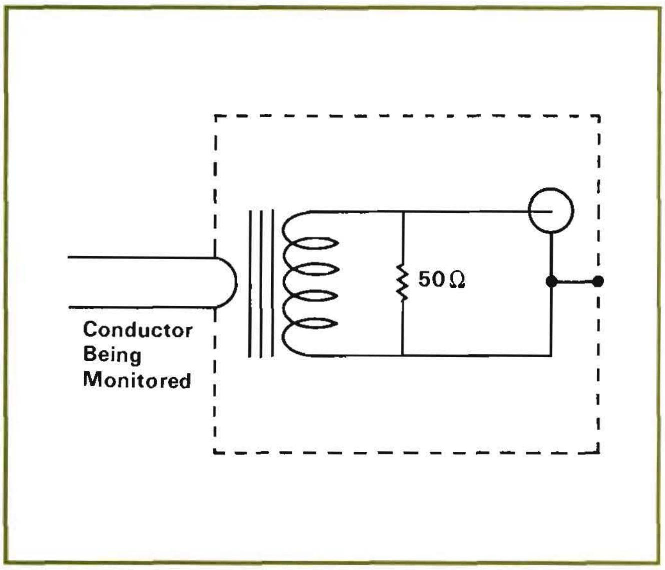


Fig. 1 Simplified circuit of the CT-1 probe.

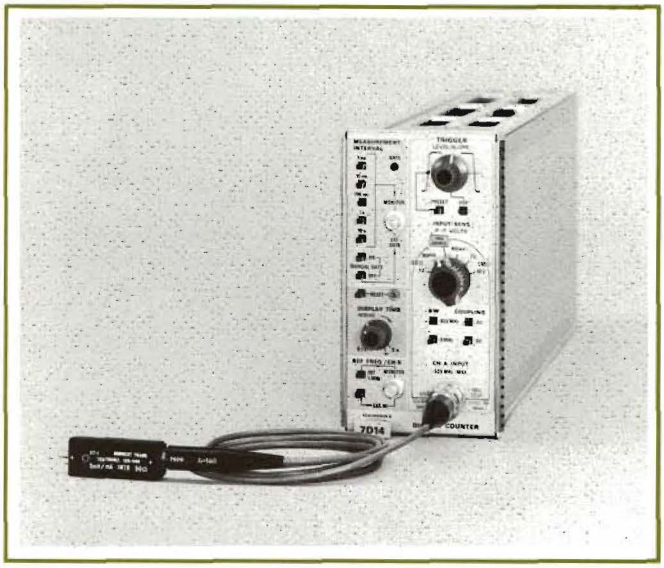


Fig. 2 The 7D14 Counter plug-in with P6041/CT-1 Probe

The 7D14 is a 525 MHz direct-reading counter. Circuit loading is often a problem when coupling to circuits operating in this frequency range. Often it is possible to use a current probe to couple the signal to be counted to the 7D14 and realize much less loading. No electrical connection is made and the current probe heads are not grounded, therefore, the possibility of accidental grounding is also avoided.

The current probe which offers the most performance coupled to the 7D14 is the P6041/CT-1. This combination makes available the full 525 MHz bandwidth of the 7D14.

Pictured at left above is a simplified circuit of the CT-1 Current Transformer. It has a frequency response of 35 kHz to 1 GHz with a sensitivity of 5 mV/mA when operated into 50Ω. It can be used with either the 50Ω or 1MΩ input impedances of the 7D14; however, the insertion impedance is lower when the 50Ω input is used (1Ω shunted by 5 uH vs 2Ω shunted by 5 uH).

The capacitance added to the conductor when passed through the CT-1 is determined primarily by the wire size. It will be 0.6 pf for No. 20 bare wire and 1.5 pf for No. 14 bare wire. This capacitance and the inductance of the conductor form a transmission line with Zo of approximately 50Ω for No. 14 wire and approximately 100Ω for No. 20.

The maximum voltage on the circuit under test is limited to 1000 V DC and the RMS current to 100 A peak with an amp-second product of 1A-us. When the amp-second product is exceeded, the core saturates and the output of the CT-1 falls to zero.

Since the input sensitivity of the 7D14 is 100 mV and the sensitivity of the CT-1 is 5 mV/mA it can be seen that approximately 20 mA must be flowing through the circuit under test to drive the counter.

The 1MΩ rather than the 50Ω input of the 7D14 can be used to effectively double the sensitivity of the CT-1, however, the insertion impedance also doubles. When operating the probe into the 1MΩ input of the 7D14 it is only necessary for 10 mA to be flowing in the circuit under test.

If the signal current is less than 10 mA, the wire can be looped through the CT-1 more than once if the conductor is small enough. The insertion impedance will go up approximately as the square of the number of times the wire is looped through the CT-1. For example, five loops will result in an insertion impedance of about 50Ω when operating into the 1 MΩ input.

SERVICE SCOPE

A PRACTICAL APPROACH TO REGULATED POWER SUPPLIES AS OPERATIONAL AMPLIFIERS

By F.J. Beckett, Engineer

From time to time, Service Scope articles are written with the intent of broadening the technician's understanding of basic circuits used in TEKTRONIX oscilloscopes rather than discussing troubleshooting techniques. Such is the intent of this article on regulated power supplies.

Most sophisticated electronic equipment uses some form of regulated power supply. Generally speaking, these supplies fall into two categories: constant voltage or the constant current form or, in some cases, a combination of both types.

By far the most common is the constant voltage type. A constant voltage generator is defined as "a two-terminal circuit element with a terminal voltage independent of the current through the element" (extract from the I.R.E. Dictionary of electronic terms and symbols). This definition implies that a constant voltage generator has a zero source impedance.

Source impedance is that impedance we see looking back into the output terminals. In the strict sense of the definition, we cannot build a power supply whose output impedance is zero.

At this point, we must ask the question, why does it matter if the output impedance is not close to zero? To answer this question, let us look at an amplifier and its power supply (Fig. 1). We see that the power supply output impedance (Z_o) appears in series with the load resistance (R_L) of the amplifier. If Z_o is not low, the result will be that the power supply will not deliver a constant voltage but will vary with I_s.

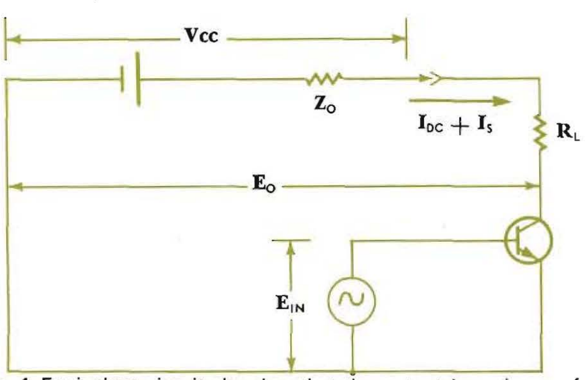


Fig. 1 Equivalent circuit showing that the output impedance of the power supply appears as part of the load.

We should keep in mind that in oscilloscopes, the varying load presented by the sweep, trigger, unblanking and other circuits could generate an I_s of several hundreds of milliamps on a peak-to-peak basis. This calls for a supply having not only a low output impedance, but it should be capable of handling wide variations in load as well.

A power supply employing feedback principles provides an ideal solution. It can accommodate varying loads and the output impedance can be made very low.

Let's take a look at the low voltage power supplies in the 453A (Fig. 3). A careful examination of the feedback networks in the amplifier portions of the circuitry shows that these are, indeed, operational amplifiers. A simplified equivalent circuit is shown at the right of each supply.

Before analyzing these supplies in detail, we need to consider operational amplifiers in general and examine some of their limitations. Shown at right is a DC analysis of the inverting and non-inverting type of operational amplifier. The analysis suggests that the most important parameter to be considered is the open-loop gain (A_{OL}). If A_{OL} is high, then the feedback resistors (R_F and R_i) are the sole factors determining the amplifier closed-loop gain. Further, we see from equation (2) that with A_{OL} very large, E_s will be very small (in the order of a few millivolts) and so E_{out} will be essentially proportional to E_{IN}.

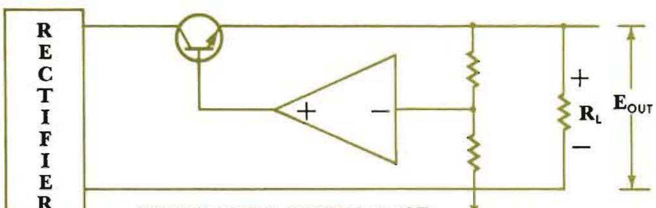
OPERATIONAL AMPLIFIER LIMITATIONS

At lower right are typical plots of A_{OL} in terms of frequency and output impedance (Z_o). We see that if we are to achieve a true constant voltage power supply, A_{OL} must be infinite. This is not possible, of course, but we can approach the ideal situtation at frequencies approaching DC. However, note that as the signal frequency increases two things happen: open-loop gain decreases and output impedance increases. The result is that we do not have a constant-voltage supply at all frequencies. Since the power supply is a common meeting point for many circuits, the variations in supply voltage caused by high-frequency circuit loads are coupled into other circuits and cause problems. This coupling can be minimized by filters and decoupling networks but is still a persistent problem to circuit designers.

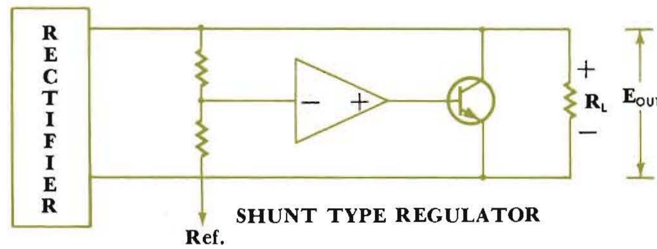
TYPICAL CONSTANT VOLTAGE SUPPLIES

Let us now turn our attention to the more practical aspects of the constant voltage power supply. In analyzing a power supply circuit, we must first recognize the type of regulator and its control amplifier. At upper right are the two types of regulator circuits commonly used, the series type and the shunt type. The most common is the series regulator for the reason of the power dissipated across the regulating element.

Once the type of regulator is determined, it then becomes an exercise to recognize the type of feedback amplifier involved and the feedback networks.



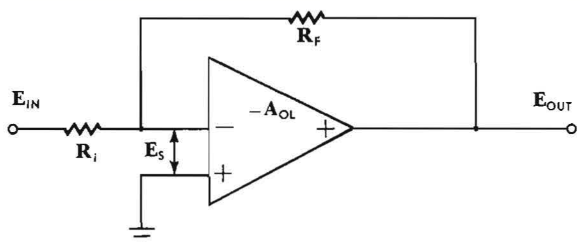
SERIES TYPE REGULATOR



SHUNT TYPE REGULATOR

DC GAIN ANALYSIS OF OPERATIONAL AMPLIFIERS

INVERTING



Now, using the superposition theorem:

$$E_S = \frac{R_F\,E_{IN}}{R_i + R_F} + \frac{R_i\,E_{OUT}}{R_i + R_F} \qquad (1)$$

and $E_{OUT} = -\,A_{OL}\,E_S$ where A_{OL} is the open-loop gain (2)

so $$-\frac{E_{OUT}}{A_{OL}} = \frac{R_F\,E_{IN}}{R_i + R_F} + \frac{R_i\,E_{OUT}}{R_i + R_F} \qquad (3)$$

rearranging Eq(3) in terms of closed-loop gain, $\frac{E_{OUT}}{E_{IN}}$ or $A_{(V)}$

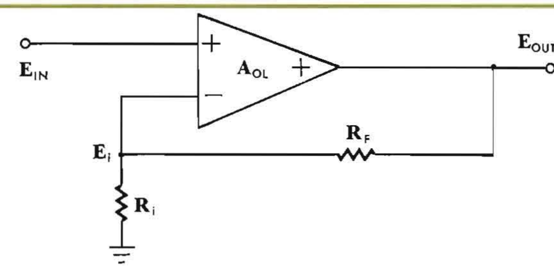
$$\frac{E_{OUT}}{E_{IN}} = A_{(V)} = -\left[\frac{\frac{A_{OL}\,R_F}{R_i + R_F}}{1 + \frac{A_{OL}\,R_i}{R_i + R_F}}\right] \qquad (4)$$

$$A_{(V)} = -\frac{A_{OL}\,R_F}{R_F + R_i\,(A_{OL} + 1)} = -\left[\frac{R_F - \frac{R_F}{A_{OL} + 1}}{R_i + \frac{R_F}{A_{OL} + 1}}\right] \qquad (5)$$

Now if $A_{OL} \longrightarrow \infty$

then $$A_{(V)} = -\frac{R_F}{R_i} \qquad (6)$$

NON-INVERTING



Using the superposition theorem:

$$E_i = \frac{R_i\,E_{OUT}}{R_i + R_F} + \frac{E_{OUT}}{A_{OL}} = E_{OUT}\left(\frac{R_i}{R_i + R_F} + \frac{1}{A_{OL}}\right) \qquad (1)$$

$$\frac{E_i}{E_{OUT}} = \frac{R_i A_{OL} + R_i + R_F}{(R_i + R_F)(A_{OL})} = \frac{R_i(A_{OL} + 1) + R_F}{(R_i + R_F)(A_{OL})} \qquad (2)$$

Now $E_{IN} = E_i$ because of the null situation between the inputs. So subst. E_{IN} for E_i and inverting Eq(2) we have:

$$\frac{E_{OUT}}{E_{IN}} = A_{(V)} = \frac{A_{OL}\,(R_i + R_F)}{R_i\,(A_{OL} + 1) + R_F} \qquad (3)$$

where $A_{(V)}$ = closed-loop gain

$$= \frac{A_{OL}\,(R_i + R_F)}{(A_{OL} + 1)\left(R_i + \frac{R_F}{A_{OL} + 1}\right)}$$

and for values of $A_{OL} \gg 1$

$$A_{(V)} = \frac{R_i + R_F}{R_i + \left(\frac{R_F}{A_{OL} + 1}\right)} \qquad (4)$$

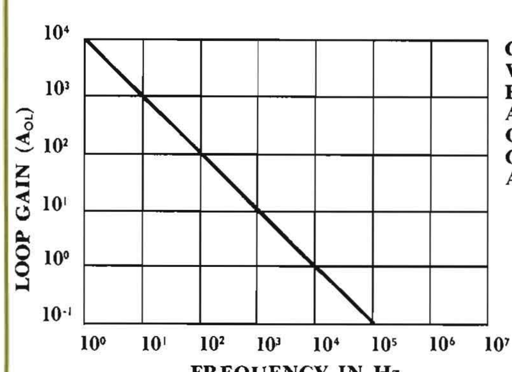
and if $A_{OL} \longrightarrow \infty$ then $$A_{(V)} = \frac{R_i + R_F}{R_i} \qquad (5)$$

$$\text{OUTPUT IMPEDANCE} = Z_O = \frac{Z}{1 + \beta A_{OL}}$$

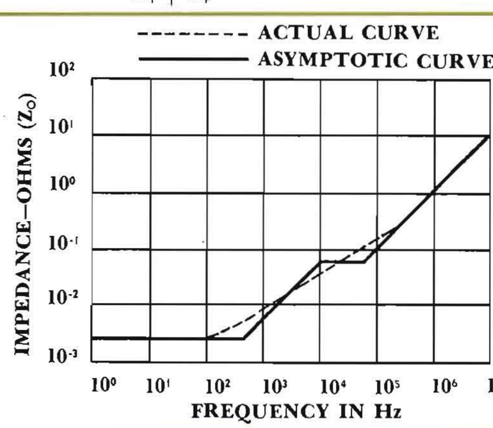
where Z_O is the output impedance with feedback

Z = output impedance without feedback

$$\beta = \frac{R_i}{R_i + R_F}$$



CONSTANT VOLTAGE FEEDBACK AMPLIFIER OPEN-LOOP GAIN CHARACTERISTIC



OUTPUT IMPEDANCE OF CONSTANT VOLTAGE REGULATED SUPPLY

Fig. 2

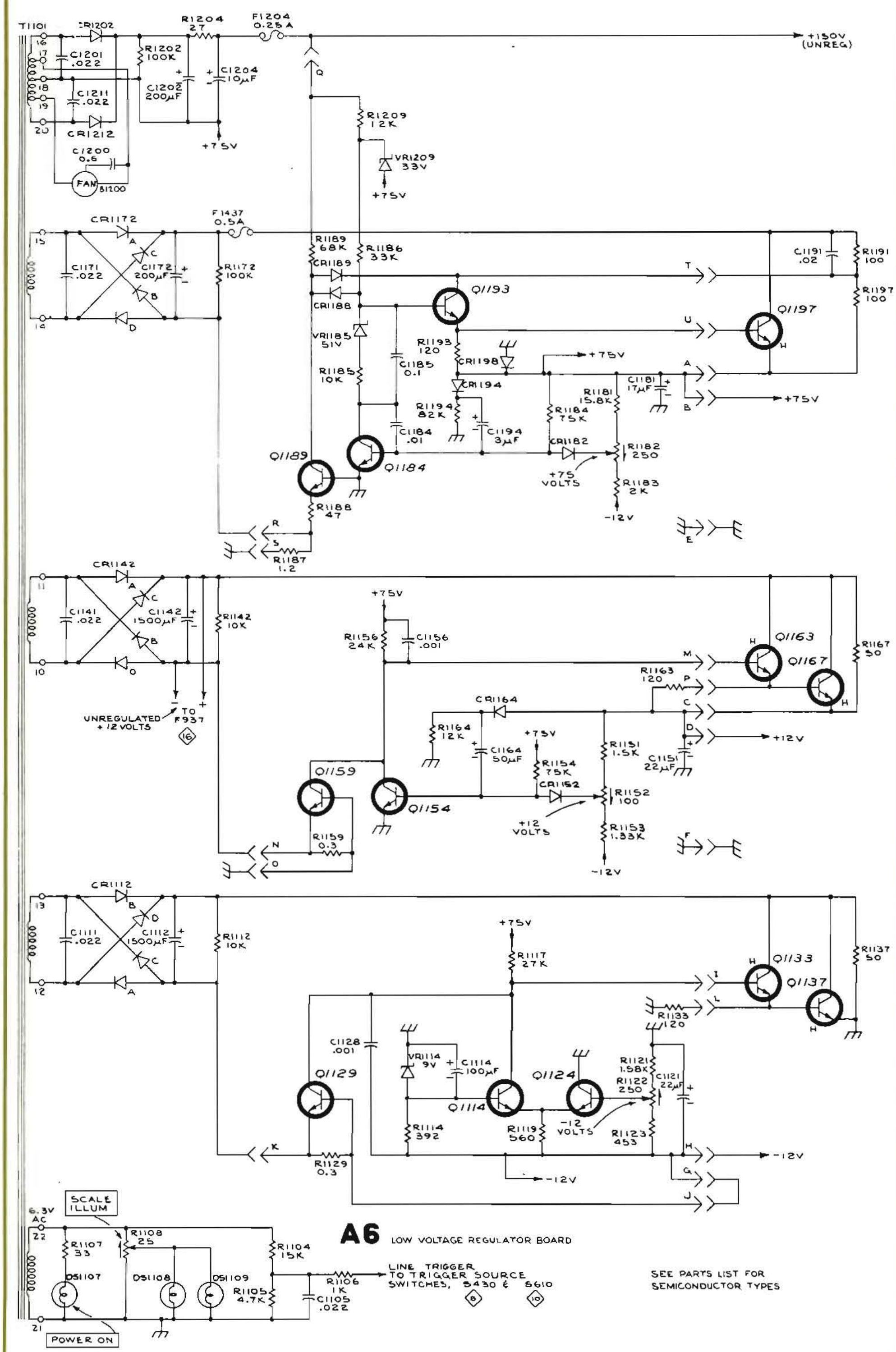
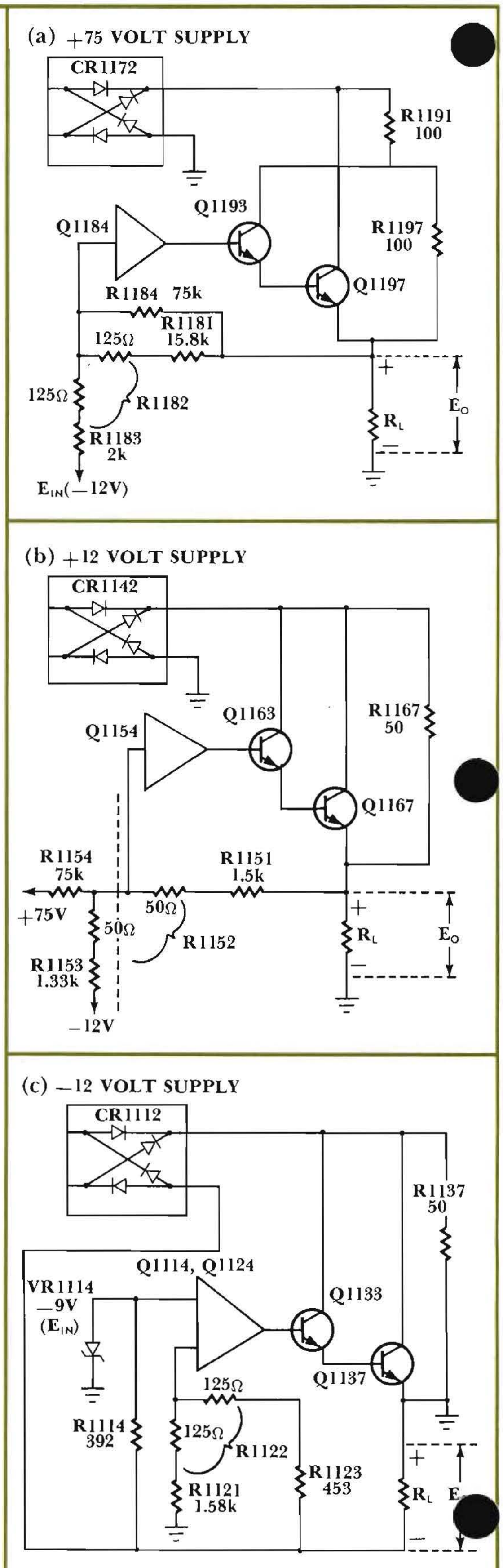


Fig. 3 Low voltage power supplies for the 453A with their simplified equivalent circuits at right.



Let's look again at the low voltage power supplies for the 453A (Fig. 3) and analyze them as operational amplifiers.

+75 VOLTS SUPPLY ANALYSIS

Fig. 3(a) shows the +75 volt supply in its simplified form. Recognize that this supply is a series regulator, Q1197 and Q1193 being the series element, with Q1184 the regulating amplifier (operating as an inverting amplifier). Notice we consider R1182, 250Ω potentiometer at mid range, half of R1182 is with R_F and the other half with R_i. R1182 is adjusted for the final value of +75 volts.

E_{IN} is the DC reference voltage for the supply.

So

$$R_F = 15800\Omega + 125\Omega \text{ in parallel with } 75000\Omega$$
$$= 13130\Omega\text{s}$$

$$\text{and } R_I = 2000\Omega + 125\Omega$$
$$= 2125\Omega$$

$$\therefore \frac{E_O}{E_{IN}} = -\frac{R_F}{R_I}$$

$$\frac{E_O}{-12} = -\frac{13130}{2125}$$

$$\therefore E_O = \frac{12 \times 13130}{2125}$$

$$= 74.2 \text{ volts}$$

A slight adjustment of R1182 will bring E_o to exactly +75 volts.

+12 VOLTS SUPPLY ANALYSIS

Fig. 3(b) shows the +12 volt supply in its simplified form. We proceed along the same lines as we did in the +75 volt analysis. Q1167 and Q1163 are the series regulator elements while Q1154 is the regulating amplifier, once again the inverting type. R1152, 100Ω pot, is the adjustment for setting the supply to +12 volts. Consider R1152 set at mid range, half of which is associated with R_F while the other half we find associated with R_i. However, the values of R_i and E_{IN} are not so apparent here. We must first calculate these values. R_i is Thevenin's equivalent resistance, while E_{IN} is the Thevenin equivalent voltage to the left of the dashed line.

So

$$R_i = \frac{(1330 + 50) \times 75000}{(1330 + 50) + 75000} \Omega\text{'s}$$
$$= 1355 \Omega\text{s}$$

$$\text{and } E_{IN} = -12 + \frac{87 \times (1335 + 50)}{(1335 + 50) + 75000} \text{ volts}$$
$$= -12 + 1.57$$
$$= -10.43 \text{ volts}$$

$$\text{now} \quad R_F = 1500\Omega + 50\Omega$$
$$= 1550\Omega$$

so finally

$$\frac{E_O}{E_{IN}} = -\frac{R_F}{R_i}$$

$$\frac{E_O}{-10.43} = \frac{1550}{1355}$$
$$= \frac{+10.43 \times 1550}{1355} \text{ volts}$$
$$= +11.93 \text{ volts}$$

A slight adjustment of R1152 will bring E_o to exactly +12 volts.

-12 VOLTS SUPPLY ANALYSIS

Fig. 3(c) shows the -12 volt supply in its simplified form. Q1137 and Q1133 are the series regulating elements. Q1124 and Q1114 are the regulating amplifiers. Notice that the simplified form is of the *non-inverting* type of operational amplifier. This is not so apparent at first glance and is determined by the fact that the reference voltage (E_{IN}) is a negative voltage and results in a negative output voltage. However, the feedback loop is connected to the opposite input of the amplifier and any change in output voltage is amplified and inverted to move the output back to its original level. E_{IN} in this case is the reference voltage provided by the zener diode VR1114. R1122, the 250Ω pot is the -12 volt adjustment, so as before, we identify R_F and R_i.

So

$$R_F = 453\Omega + 125\Omega$$
$$= 578\Omega$$

$$R_I = 1580\Omega + 125\Omega$$
$$= 1705\Omega$$

$$\therefore \frac{E_O}{E_{IN}} = 1 + \frac{R_F}{R_I}$$

$$\frac{E_O}{-9} = 1 + \frac{578}{1705}$$
$$= \frac{2283}{1705}$$

$$\text{hence} \quad E_O = \frac{-9 \times 2283}{1705}$$
$$= -12.05 \text{ volts}$$

A slight adjustment of R1122 will bring E_o to exactly -12 volts.

CONCLUSION

In summary, we find that the typically high open-loop gain and low output impedance of operational amplifiers make them ideal for use in achieving a constant voltage power supply. They do, however, have limitations as to the range of frequencies over which they can maintain a constant output voltage.

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