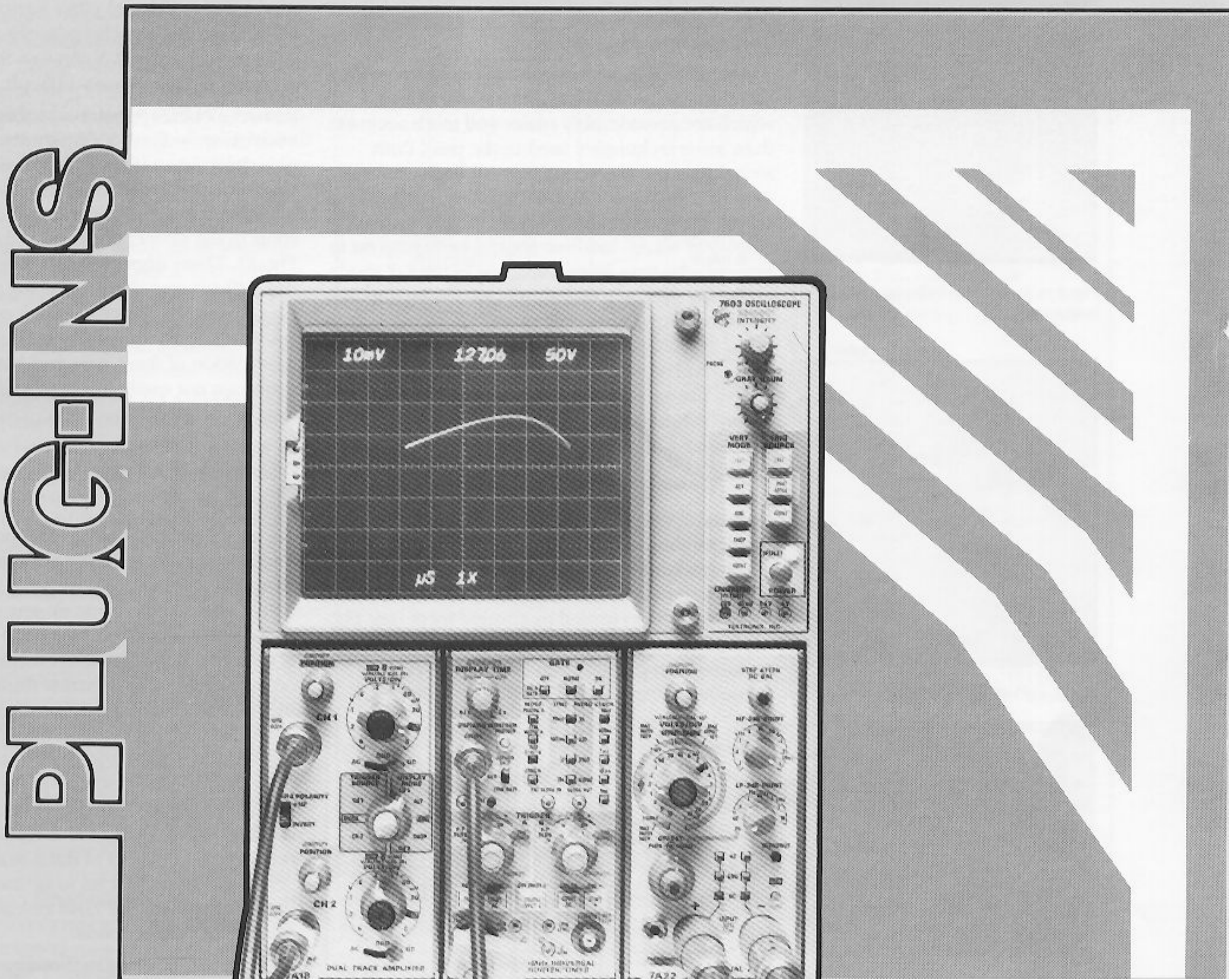
X-Y Displays with Interval Timing for Measuring SOA



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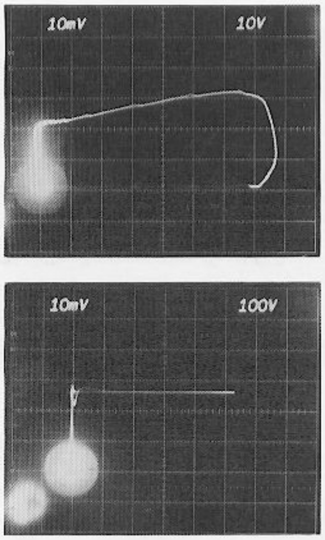


Fig. 2 — Standard X-Y display (with bright spots).

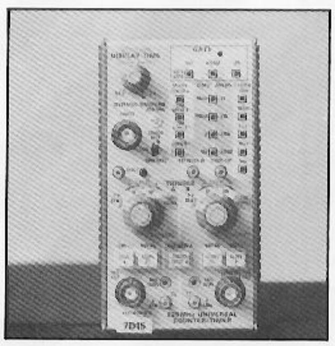


Fig. 3 — 7D15 Universal Counter/Timer.

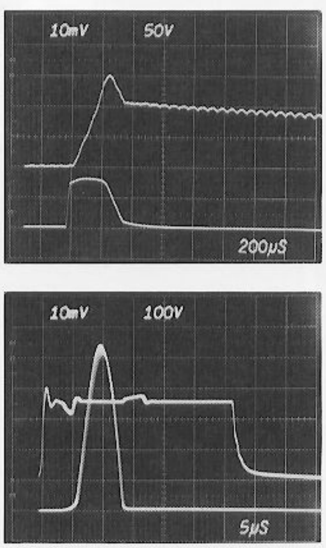


Fig. 4A — The waveforms shown are from one side of the complementary output pair of the vertical deflection system (upper) and the horizontal (lower) at sweep start. Note that both V_{ce} and I_c are near to peak level simultaneously. This requires further examination.

Introduction

Measuring the energy consumed by a device is particularly important when evaluating systems that have been designed primarily to drive inductive loads, such as motor control systems with snubber networks, inverter or switch regulated power supplies, or magnetic deflection systems. These measurements are typically complicated to make because they require the measurement of power for specific time intervals of a device's in-circuit operating cycle.

This application note shows two techniques for making this power over time measurement, which are considerably easier and more accurate than some techniques used in the past. Both techniques use the versatility and high performance of a Tektronix 7000-Series Plug-In Oscilloscope. The first method, which employs an X-Y display of an AC loadline should be of interest to anyone who uses an oscilloscope in the X-Y mode to display pressure vs. volume, torque vs. angular displacement, or current vs. voltage. This technique not only provides an accurate measure of an interval of time on an X-Y display, but also allows the user to blank out annoying bright spots, common to X-Y displays.

The Measurement Problem

Transistor Safe Operating Area (S.O.A.) specifications show users how much stress a device can withstand before it goes into secondary breakdown and fails. These SOA characteristics are generally presented in graphic form (see Fig. 1) specifying the maximum time that a device can sustain given power levels without going into secondary breakdown.

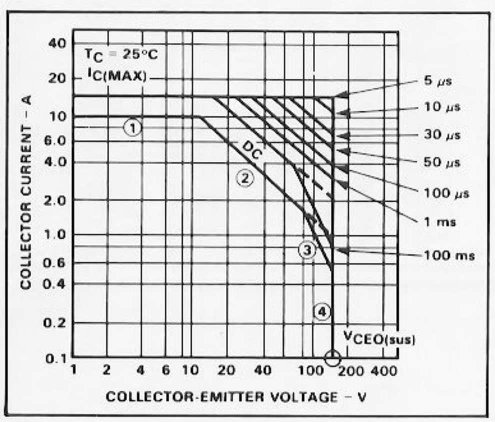


Fig. 1 — Typical safe area.

The most common technique for measuring how much energy a device is actually consuming is to display collector current I_c vs. collector-emitter voltage V_{ce} on an oscilloscope in an X-Y display.

With the oscilloscope in the X-Y mode, you no longer can use the oscilloscope time-base for timing measurements. To return the timing information to the display, the Z-axis of the oscilloscope can be modulated with a time-mark generator, producing dots on the I_c vs. V_{ce} curve. You can then count the dots to determine how long the device is exceeding a particular power level.

At best this technique is tedious and cumbersome. It also has two other limitations. First, it is often difficult to synchronize the time-mark generator with the X-Y display, thus making accurate measurements difficult.

Second, bright spots are a problem. The fast transitions on the X-Y display are often very faint, especially when viewing low rep rate phenomena. To see these transitions, the beam intensity is generally increased, causing bright spots in the slower portions of the display (see Fig. 2). These annoying bright spots make viewing difficult and also tend to fog photographic film. Using the Z-axis to blank out these bright spots will solve this problem, but time-marker modulation of the Z-axis and blanking of bright spots can not easily be employed at the same time.

The X-Y Plus Time Measurement Package

Tektronix has now solved this problem of timing and bright spots with the addition of a 7D15 Universal Counter/ Timer plug-in module to a 7000-Series oscilloscope measurement package (see Fig. 3). The 7D15 Universal Counter/Timer is a unique digital measurement device that not only provides very accurate timing information, but selective blanking of the display as well. Using an internal clock, it times a selected interval of the X-Y display and at the same time causes the Z-axis to blank out the portion of the display that is outside the timed interval. The duration of the selected time interval is displayed via the crt readout. Adjustment of the A and B trigger levels selects the time interval to be measured. As used with this system, the 7D15 can accurately resolve up to ±20 nanoseconds.

7000-Series Plug-in Oscilloscopes provide other convenient features for producing X-Y displays. Any of the standard 7000-Series Amplifiers can be plugged into a horizontal compartment of a 7000-Series Mainframe in place of a time-base plug-in to provide horizontal deflection for the X-axis. Here the 7A22 Differential Amplifier plug-in is used and provides from 10μV to 10V sensitivity, selectable input filtering, and up to 100,000:1 CMRR. Its differential input allows signals to be referenced to levels other than ground potentials.

Displaying The AC Loadline Of A TV Output Amplifier

In a magnetic deflection system like that used in a video monitor, the output transistors come under high stress due to the phase difference between the collector current (I_c) and the collector-emitter voltage (V_{ce}). Fig. 4A shows a standard oscilloscope time display I_c and V_{ce} of the output transistor of both vertical and horizontal output amplifiers of a video display monitor. I_c and V_{ce} are at high levels simultaneously for a short interval of time. Under this condition, secondary breakdown can occur. Certain power levels can be tolerated, but for how long? SOA data is helpful in selecting a device for a design, but in-circuit testing of the device is required to assure that it is not being asked to perform beyond its limits.

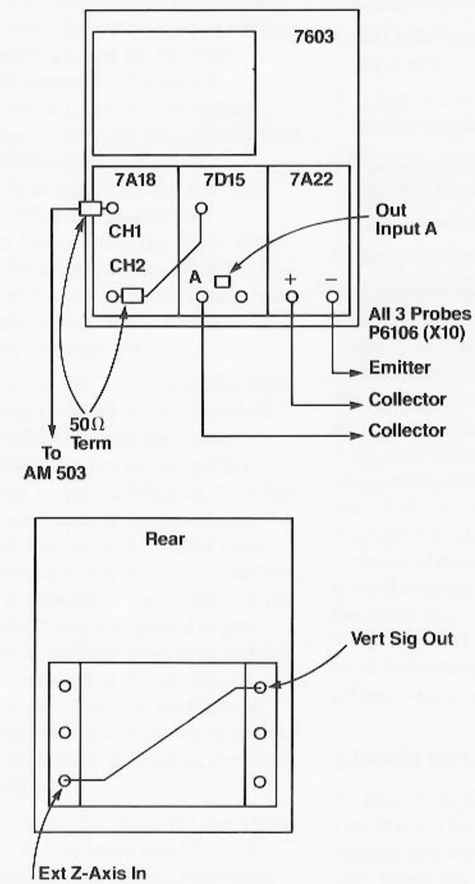
Fig. 5 shows a test set-up for examining the operating area of the device by using an ac loadline. This measurement package uses a Tektronix 7603 Plug-in Oscilloscope, the 7D15 Digital Counter/Timer, a 7A18 Dual Trace Amplifier, a 7A22 Differential Amplifier and a P6302/AM 503 Current Probe. The 7603 Mainframe used in this example is equipped with an X-Y compensation conversion kit (040-0718-00), which matches the vertical and horizontal compartments out to 2 MHz at 2° phase difference. The P6302/AM 503 allows in-circuit measurements of I_c. The output of the AM 503 Current Probe Amplifier is connected to channel 1 of the 7A18 for providing the vertical deflection of the display. V_c is acquired differentially with the 7A22, using the emitter voltage as reference.

The 7D15's timing gate is routed through channel 2 of the 7A18 to the external Z-axis connector (see the rear panel connection in Fig. 5). The channel 2 sensitivity and position settings serve as a conditioning amplifier to control the Z-axis blanking and contrast ratio. The collector voltage is used to trigger the 7D15 through its channel A trigger input. By varying both the slope and level controls of both 7D15 trigger channels, nearly any portion of the display may be selectively blanked or intensified and timed while in the "TIM A→B" mode. Although only one trigger source was used here, A and B triggers may be derived independently. For instance, trigger A can start the interval count at some point on the* vertical signal and trigger B can stop the count on some point on the horizontal signal. In many cases, as here, only one source is necessary. The collector voltage was chosen for ease of triggering since it is smooth and has a well-behaved shape.

Note also, that since only the timed interval is being displayed, the annoying bright spots are blanked out. (see Fig. 4B). Even when viewing fast transitions, you can turn up the display intensity for easy viewing.

*In this case, the AM 503 calibrated output is below the 100 mV hysterisis window of the 7D15 external triggers.

To further illustrate the effectiveness of this method of measuring the Operating Area, let's take a look at the horizontal output system of the video monitor. Fig. 4A shows the I_{ce} and V_{ce} signals vs. time. Note that these signals have faster switching times than the vertical output system signals. Fig. 4B shows, however, that the X-Y display of the horizontal signals has the same quality as the X-Y display of the vertical signals.



CONTROL SETTINGS 7603

7603 (with X-Y Comp)

Trigger Source	LEFT
Vert Mode	LEFT

7A18

Display Mode	CH 1
Trigger Source	CH 2
CH 2 Polarity	INVERT
Coupling CH 1, CH 2	dc
Sensitivity, CH 1	10 mV/Div
Sensitivity, CH 2	As Required

7A22

Coupling	dc
Offset	As Required
Sensitivity	As Required
HF-3 dB Point	As Required
LF-3 dB Point	As Required

7D15

Mode	TIM A→B
Averg	X1000
Clock	10 ns
Gate	NORM
Displayed Waveform	PSEUDO GATE
Display Storage Time	ON (As Required)
Trigger Inputs	
Coupling A and B	dc
P-P Sensitivity A and B	As Required
Slope A	+
Slope B	−
B Source	A INPUT OUT

Fig. 5 — Test set up for X-Y/T|measurements.

Timing Accuracy

In this system configuration, accuracy to ±50 ns is typically attainable with the 7D15. If care is taken with the interconnection of cables and the intensity setting, as much as ±20 ns accuracy can be expected. The 7D15 itself can resolve an order of magnitude finer than 20 ns, but it is limited in this case by system introduced error like Z-axis risetime, internal propagation delays and visual interpretation. Even with this error, the resolution and accuracy is more than sufficient for determining the Operating Area of typical semiconductor devices.

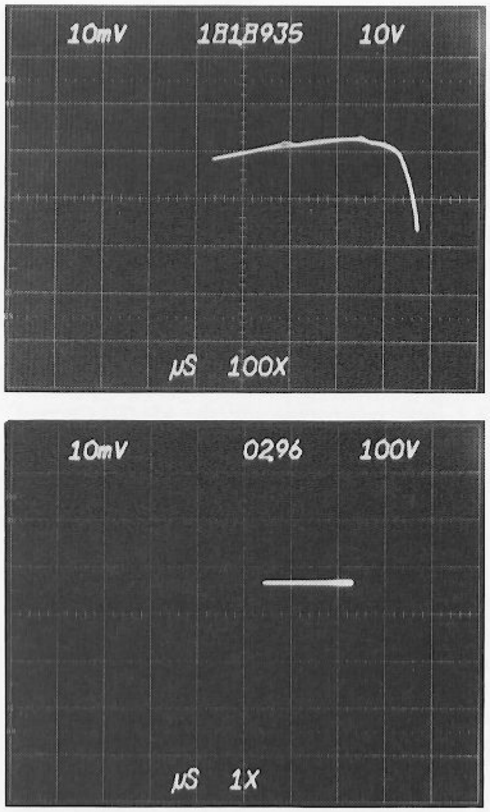


Fig. 4B — This demonstrates the improved quality of the display when annoying bright portions are eliminated. Note the addition of the time information displayed by the crt readout. This time is measured from beginning to end of the intensified zone.

System Bandwidth

The bandwidth of the vertical system with the 7A18 is 75 MHz with a step response of approximately 5 ns. When equipped with the X-Y compensation kit (040-0718-00), the maximum horizontal bandwidth is 2MHz at 2° phase difference. With the 7A22 the bandwidth is limited at less than 1 MHz. If a 7A13 Differential Amp is used, the full 2 MHz may be attained with a step response of approximately 180 ns.

An Alternate Measurement Technique

To determine the Operating Area using an X-Y display and the 7D15 is a very convenient technique. The loadline display is easy to understand and measure, and the 7D15 is a test and measurement tool that can be put to many other uses on your test bench.

An alternate method to measure the energy consumed is also available, due to the flexibility of the 7000-Series Plug-in concept. Fig. 6 shows the I_c and V_{ce} waveforms vs time. Below them is a display of the product of these two waveforms, or the instantaneous power dissipated by the device versus time. Note the readout of the power deflection factor in VA (watts) per division. With this standard Y-time display you can obtain the same information as from the X-Y display. You may select a constant power level, and measure the time and the power is above this level. The time can be measured visually using the time calibrated horizontal divisions.

The power vs time display gives another picture of the power sustained by the device. With this display it is simple to approximate the energy sustained by the device.

The Fairchild Power Data Book, 1976, suggests this approach (see Fig. 7). A rectangular section is constructed around the potential critical area of the display. If $P_b \Delta t_b$ is within the SOA given by the vendor, the actual energy dissipated by the device $P(t)\Delta t_b$, which is less than $P_b \Delta t_b$, is also safe.

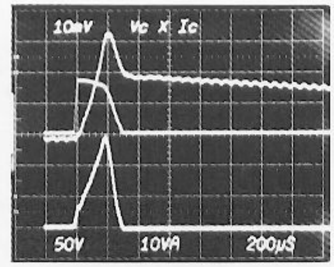


Fig. 6 — Display of I_c overlay with V_{ce} and P at the bottom.

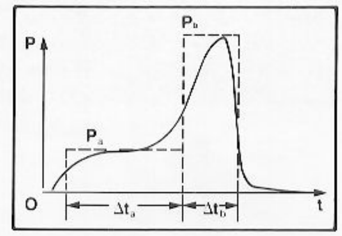


Fig. 7 — Determining SOA by rectangular approximation.

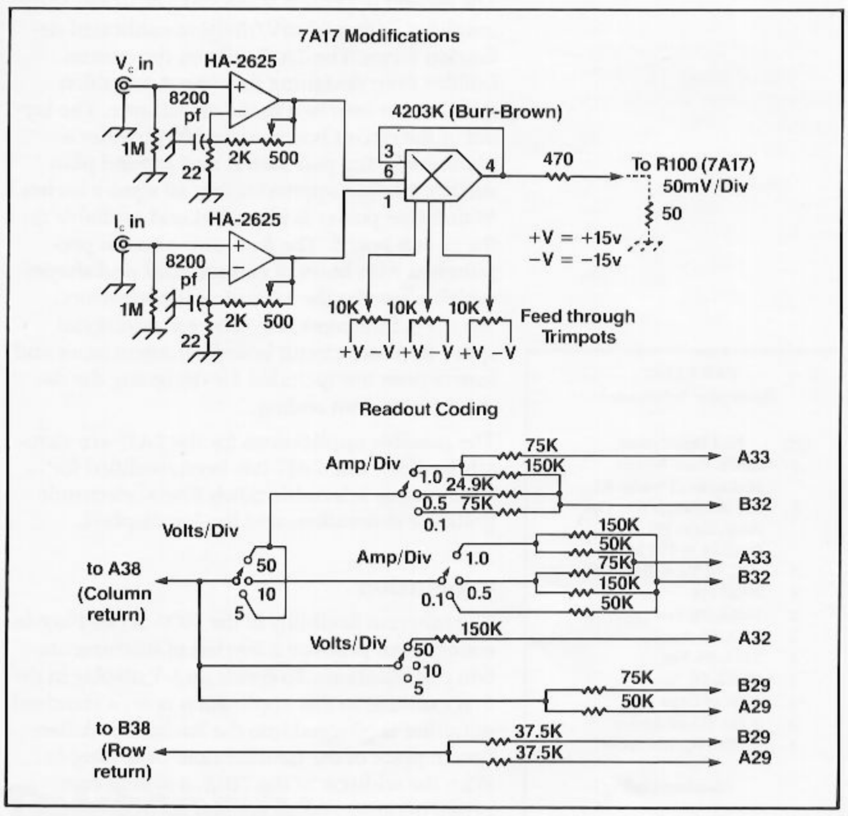


Fig. 8 — Multiplier schematic.

An Easy Way To Build Custom Instrumentation.

Power cannot commonly be measured directly with most oscilloscopes. The display in Fig. 6 was created using a custom built 7000-Series plug-in, designed to multiply a current and a voltage signal. Instructions for building this custom plug-in are shown in the appendix at the end of this application note.

Often there is a special or unique measurement problem that cannot be resolved by standard instrumentation, where the cost for some elaborate specialized system cannot be justified. Tektronix has an inexpensive alternative. 7000-Series Instruments provide two ways to build custom or special purpose plug-ins for use in a 7000-Series Mainframe.
The first approach is to construct the needed circuitry in a Blank Plug-in Chassis kit (040-0553-01). This kit contains the basic mechanical elements for a 7000-Series Plug-in, including a vector board, plug-in frame, and securing hardware. There are no active elements for interfacing provided with the kit.

The second approach is the 7A17 dc to 150 MHz amplifier with a 50 mV/division calibrated deflection factor. The 7A17 relieves the custom builder from designing the output amplifier, which must interface to the mainframe. The layout of the circuit board assembly provides a blank soldering pad matrix and ground plan surface totaling approximately 40 square inches. Mainframe power is identified and available on the circuit board. The front sub-panel is prepunched with holes of various sizes and shapes which allow for the mounting of connectors, switches, indicators, etc. There is additional space for more circuit boards or attenuators and instructions are included for designing the desired crt readout coding.

The possible applications for the 7A17 are virtually endless. The 7A17 has been modified for such uses as selectable notch filters, electronic graticule generation, and log-log displays.

Conclusion

The inherent flexibility of the 7000-Series Plug-in concept can produce a myriad of instrumentation combinations. To create an X-Y display in the first example in this application note, a standard amplifier is plugged into the horizontal deflection in place of the familiar time-base plug-in. With the addition of the 7D15, a system comprised of rather common elements expands into a unique measurement system, one giving not only accurate timing information, but providing selective blanking of annoying bright spots as well. In the second example, a unique and useful display of power vs. time is created with an easy-to-build custom 7A17 Plug-in Amplifier. Both examples are further proof that Tektronix provides the higher level of performance necessary for today's complex measurement problems.

Appendix

Construction of An I_c X V_{ce} Multiplier Plug-in

Operation

The multiplier plug-in described in the previous application note was designed to meet the following requirements:

1. 800 kHz bandwidth with better than 2% dc accuracy.
2. I_c input compatible with the AM 503 Current Probe amplifier output of 10 mV/division.
3. V_{ce} input compatible with 7A18/7603 Vert Signal Out of 25 mV/division.
4. Calibrated display range of 1 to 100 VA.
5. Inexpensive and easy to construct.

The current signal (I_c) is acquired with a P6302/AM 503 Current Probe, as for the X-Y display, and input directly into the 7A17 Custom-Built Multiplier I_c input. The AM 503 attenuates the current signal, providing a 10 mV/division calibrated output into 50Ω. The 7A18 Amplifier is used to acquire the V_{ce} signal and attenuate it. The V_{ce} signal is routed through the 7A18, and transmitted to the 7A17's V_{ce} input through the 7603 Vert Signal Out connector. In order to obtain the correct crt readout for a calibrated display of the product, the two knobs of the 7A17 must match the respective settings of the 7A18 and AM 503 deflection factor controls. The switch positions of the 7A17 compute the correct crt readout to correspond to the display.

Circuit Description

As shown in Fig. 8, a very high bandwidth Op-Amp (HA-2625) amplifies each signal. The signals are then fed to an analog multiplier module. There are many types of analog multipliers available commercially. The Burr-Brown 4203K Multiplier-Divider IC was chosen for its exceptional ac performance, having a 2 MHz small signal bandwidth, fast settling time, and rather good noise figures. The 4203K is extremely simple to use and is completely self-contained. The IC's output is fed to the existing output amplifier in the 7A17, which drives the vertical deflection. See Fig. 9 for a parts breakdown. This construction note shows one possible use for the 7A17. The I_cX V_{ce} multiplier plug-in is neither a high performance nor a particularly versatile instrument, but it does meet the unique measurement requirements it was designed for. The simplicity of this design affords some important advantages over available instrumentation: its price is low and it can be built in only a few hours.

PART LIST
(Multiplier Schematic)

Qty.	Part Description
1	4203K Burr-Brown Multiplier/Divider IC
2	HA-2625 High BW Op-Amp, Gain BW Product = 100 MHz
3	10K, 10 Turn Trimpot
2	500Ω Pot
2	1MΩ, 5% Res.
2	22Ω, 5% Res.
2	2KΩ, 5% Res.
1	470Ω, 5% Res.
2	8200 pf Caps
2	8 Pin TO-99 Socket
1	10 Pin TO-100 Socket

(Readout Coding)

Qty	Part Description
2	D.P. 3T. switch
1	24.9K, 1% Res.
2	37.5K, 1% Res.
3	50K, 5% Res.
4	75K, 5% Res.
4	150K, 5% Res.

Fig. 9 — Part List.

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