NASA Technical Paper 2554

February 1986

NASA-TP-2554 19860012284

Programmable, Automated Transistor Test System

Long V. Truong and
Gale R. Sundburg

NASA
Technical
Paper
2554

1986

Programmable, Automated Transistor Test System

Long V. Truong and
Gale R. Sundburg

Lewis Research Center
Cleveland, Ohio

NASA
National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

Summary

A programmable, automated transistor test system was built to supply experimental data on new and advanced power semiconductors. The data will be used for analytical models and by engineers in designing space and aircraft electric power systems. A pulsed power technique was used at low duty cycles in a nondestructive test to examine the dynamic switching characteristic curves of power transistors in the 500- to 1000-V, 10- to 100-A range. Data collection, manipulation, storage, and output are operator interactive but are guided and controlled by the system software.

Introduction

With the emergence of the space shuttle we are entering a new era of large, high-power spacecraft. Over the past 15 years the NASA Lewis Research Center has been instrumental in developing high-voltage, high-power transistors and other semiconductors for a myriad of fast, power-switching applications. The power-switching transistors are providing baseline technology for future electric power management and distribution systems for the space station and other large space and aircraft applications.

As the power levels of switching transistors have increased to several tens of kilowatts, so have the problems in their application. The switching and control of large amounts of power at microsecond switching speeds have magnified the need for accurate, repeatable data and switching characteristics under representative power drive and temperature conditions. In most cases dependable switching characteristics are not available from the manufacturers or transistor developers. With some transistors and new classes of semiconductors there remain undefined switching parameters.

If one relies on manual acquisition and reduction of new data into graphical form, the characterization of power-switching transistors can be very time consuming. This method is subject to problems with accuracy, repeatability, and application to large numbers of transistors. Because of the sheer number of transistors—types, classes, and different manufacturers—coupled with the limited number of available workers and the need for highly accurate data on switching characteristics under specified power and frequency conditions for circuit applications and modeling, computer interaction was added to the transistor test system.

This report describes the programmable, automated transistor test system (PATTS) and its utilization to evaluate bipolar transistors and Darlingtons and such metal-oxide-semiconductor field-effect transistors (MOSFET's) and special types of transistors as can be accommodated with the PATTS base drive. The PATTS is fast, accurate, and reproducible and has the flexibility of software control. In addition, it establishes a library of test data on disks, tapes, and hard copies for future reference. Appendix A describes the screening tests; and appendix B, the characterization tests.

PATTS Hardware Configuration

The PATTS is a computerized numerical control system with an operator-interactive computer terminal that enables a full range of transistor tests to be executed. It produces accurate, complete sets of parametric data and characterization waveforms. The PATTS (fig. 1) has three main parts: the waveform-processing system, the base drive, and the test circuit.

Waveform-Processing System

The waveform-processing system is a combination of instruments. Together these instruments automate the entire waveform test, the measurement process, and the data storage and provide graphical output as hard copies for documentation. The basic components are

(1) A graphics desktop computer, Tektronix 4052A
(2) A digitizing oscilloscope, Tektronix 7854
(3) Disk and tape drives
(4) A printer and hard-copy unit

Transistor Base Drive

The transistor base drive contains a programmable general-purpose interface bus (GPIB) and operates at high current. A dual unit, it can deliver a pulsed train of current up to 25 A in magnitude to a single-base transistor or to a Darlington (with two bases). Each pulsed train may be positive or negative and is controlled independently. Duty cycles from 5 to 90 percent are selectable. Switching frequencies from dc to 200 kHz are also provided. The main components in the base drive are (fig. 2)

(1) A Z–80 processor board, Pro-Log 7803
(2) An IEEE–488 interface board, ZT–7488

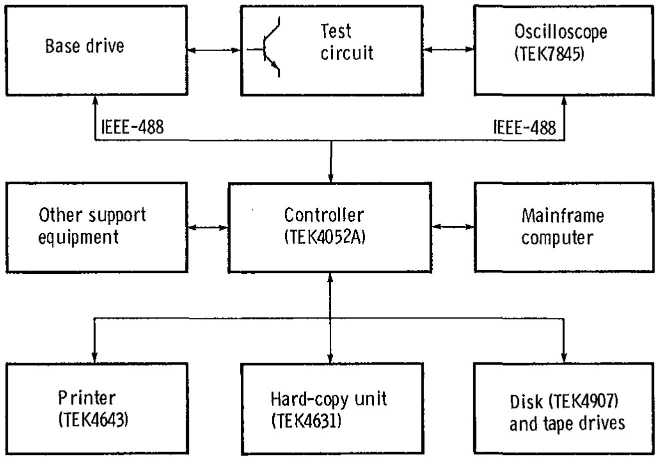

Figure 1.—PATTS hardware configuration.

(3) A transistor-transistor logic (TTL) input/output board, Pro-Log 7604
(4) A digital signal-processing board
(5) A digital-to-analog (D/A) control board
(6) An analog output board
(7) A power supply

Transistor Test Circuit

The transistor test circuit (fig. 3) serves as the basis of all characteristic tests. All of the instruments are calibrated in accordance with NASA Lewis' standard quality assurance provisions. The individual components of interest in the test circuit setup include

(1) V_{CC}: two Hewlett-Packard power supplies (model 6438, 350 V, 35 A per unit) slaved together in parallel
(2) D_1, D_2: high-current, high-voltage, fast-recovery diodes
(3) R_l: load resistor
(4) L_l: load inductor (range, 20 to 1000 μH, selectable)

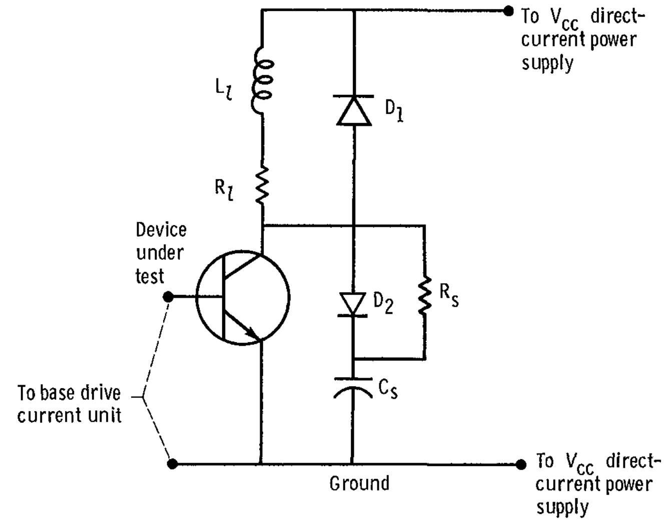

Figure 3.—Simplified diagram of test circuit. (See table I for test circuit component values.)

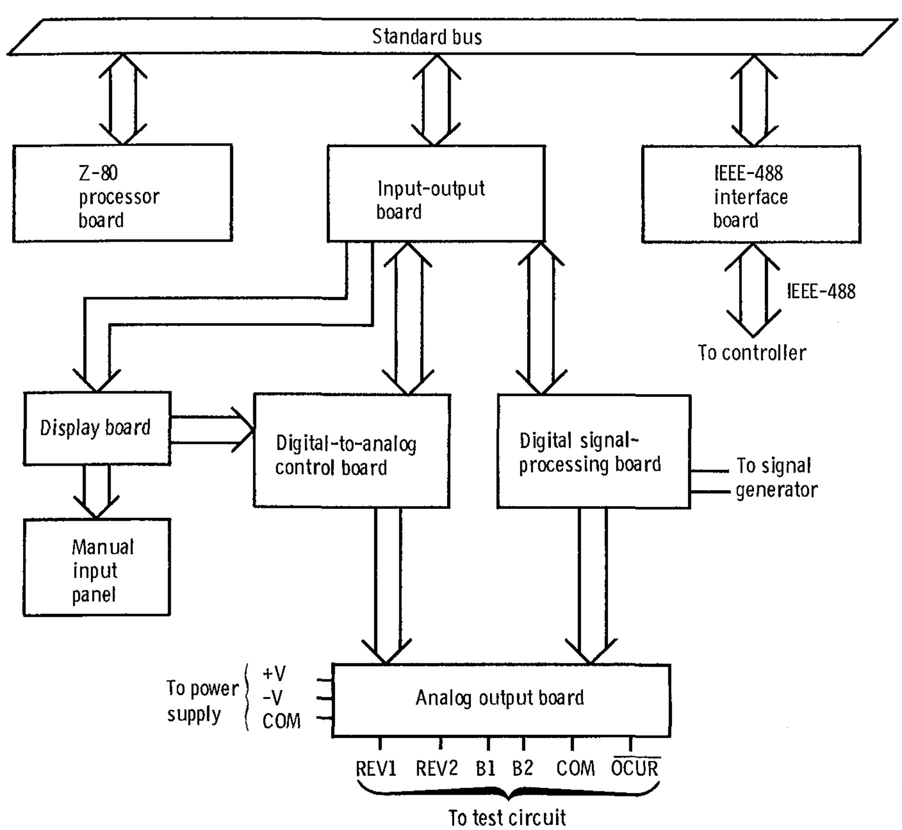

Figure 2.—Transistor base drive.

(5) C_s: snubber capacitor (range, 0.01 to 0.05 μF, selectable)
(6) R_s: snubber resistor (range, 20 to 50 Ω, selectable)

PATTS Software Structure

The PATTS software (figs. 4 and 5) was developed under various types of computer languages including extended Basic, Assembly, and GPIB. All tasks and test procedures are operator interactive but are guided and controlled by the computer. In this way the system is user friendly and minimizes operator errors. Although a large software library has been developed for PATTS, additional program modules will be added to expand the test data analysis capacity.

The PATTS programs or program modules listed on the npn transistor test menu (main menu) are briefly described here. The control program module is not listed on the main menu. The control program module moves the individual system program modules in and out of the operating memory area (fig. 5) according to operator command.

The first program module, main menu, is used to display the PATTS options. It transfers system control to the control program module after each selection is made from its menu. The second program module, help/introduction, is used to help the operator get acquainted with PATTS and assist him or her in case of operational difficulties. The third program module, base drive remote control, is used to set up the base current for the transistor under test. It also provides "handshaking" between the base drive, the controller, and the mainframe computer. The fourth program module, initialization, is used to define and initialize all of the common variables in the system. The fifth program module, constant data input, enters data obtained from the screening test (described in the next section), input test condition parameters, and other necessary information. The sixth program module, test processing, provides all of the measurement options for the transistor under test. The seventh program module, file management, is used to save or retrieve test data from tapes, disks, and the extended memory. The eighth program module, output package, is used to review or obtain test data as hard copies with options to change, modify, and select variables for output. The ninth program module, termination routine, is used to confirm the termination of the test.

Operating and test procedures for each of the modules in the main menu are defined in greater detail in appendix B.

Transistor Evaluation Procedure

Procedures for evaluating power transistors are divided into two groups: screening tests done on other instruments to establish device ratings and parameters, and characterization tests done on the PATTS. The data from the screening tests are entered by the operator into the computer terminal for inclusion in the computer's data bank for a specific transistor. For the characterization tests all data, waveforms, and timing information are automatically entered via the digitizing oscilloscope into the system memory for storage or processing according to a preestablished program.

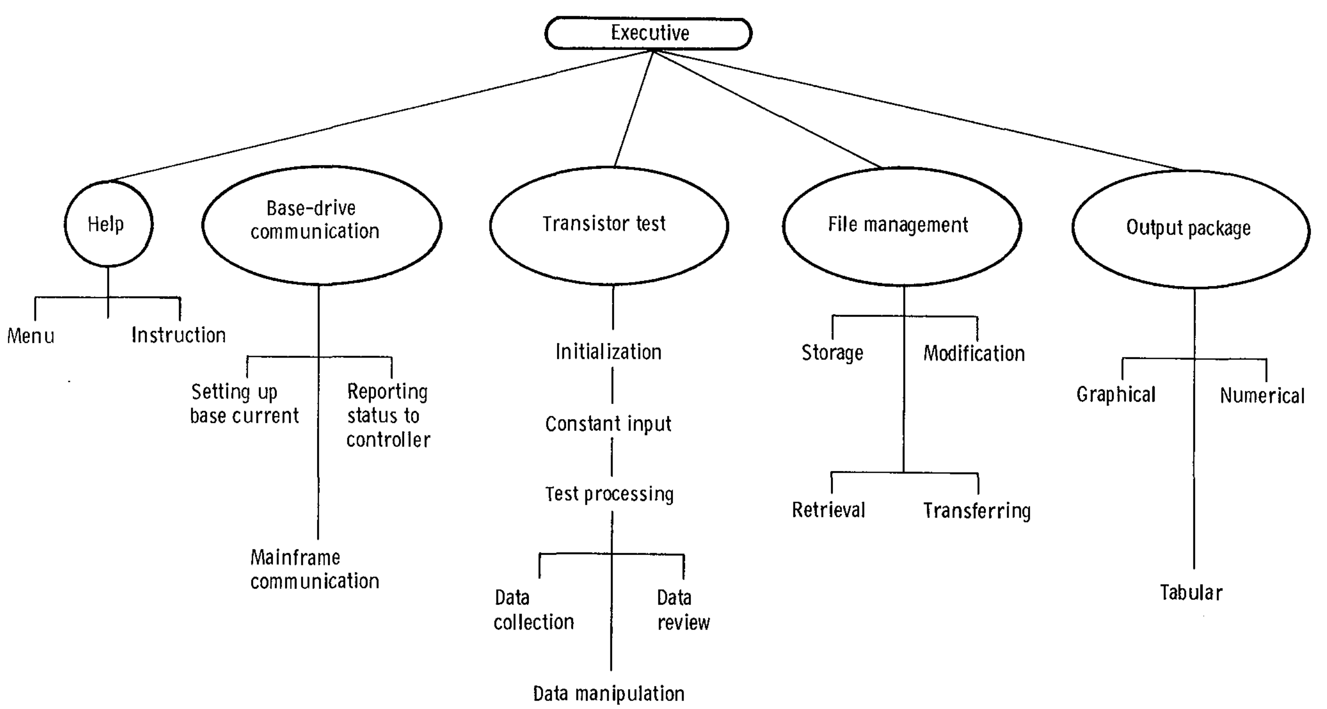

Figure 4.—PATTS software structure chart.

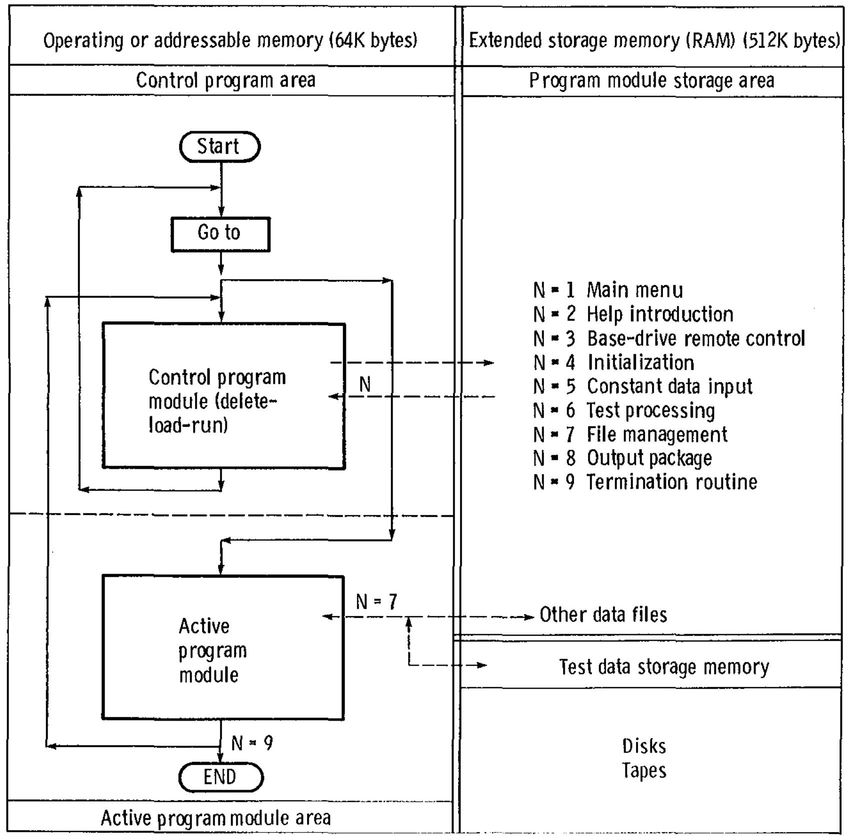

Figure 5.—PATTS software memory allocation.

Screening Tests

Screening tests are made on each transistor to establish ratings and to set parameter values and limitations for the characterization tests. The ratings and parameters shown on the simplified test circuit diagram (fig. 6) are defined as

BV_{CEO},I_{CEO} collector-emitter breakdown voltage and collector-emitter leakage current with open base

BV_{CBO},I_{CBO} collector-base breakdown voltage and collector-base leakage current with open emitter

BV_{EBO},I_{EBO} emitter-base breakdown voltage and emitter-base leakage current with open collector

Step-by-step procedures for these tests are given in appendix A.

Characterization Tests

The test circuit for the characterization tests is set up as shown in figure 3. Measurements to be made automatically are the dynamic switching characteristic waveforms, switching times, and dynamic current gain. Specific characteristics and the related waveforms are as follows:

Characteristic	Waveform
I_b	base current waveform
I_c	collector current waveform
V_{ce}	collector-emitter voltage waveform
P_{loss}	power loss waveform, or product of V_{ce} and I_c curves
E_{loss}	energy loss waveform, or integration (area under power loss waveform) of product of V_{ce} and I_c curves
I_c vs V_{ce}	collector current versus collector-emitter voltage waveform
t_d	delay time, or time from application of input base current until output collector current has reached 10 percent of its final value
t_r	rise time, or time required for output collector current to go from 10 to 90 percent of its saturation value
t_s	storage time, or time from removal of input base current until output collector current goes from its saturation value to 90 percent of that value

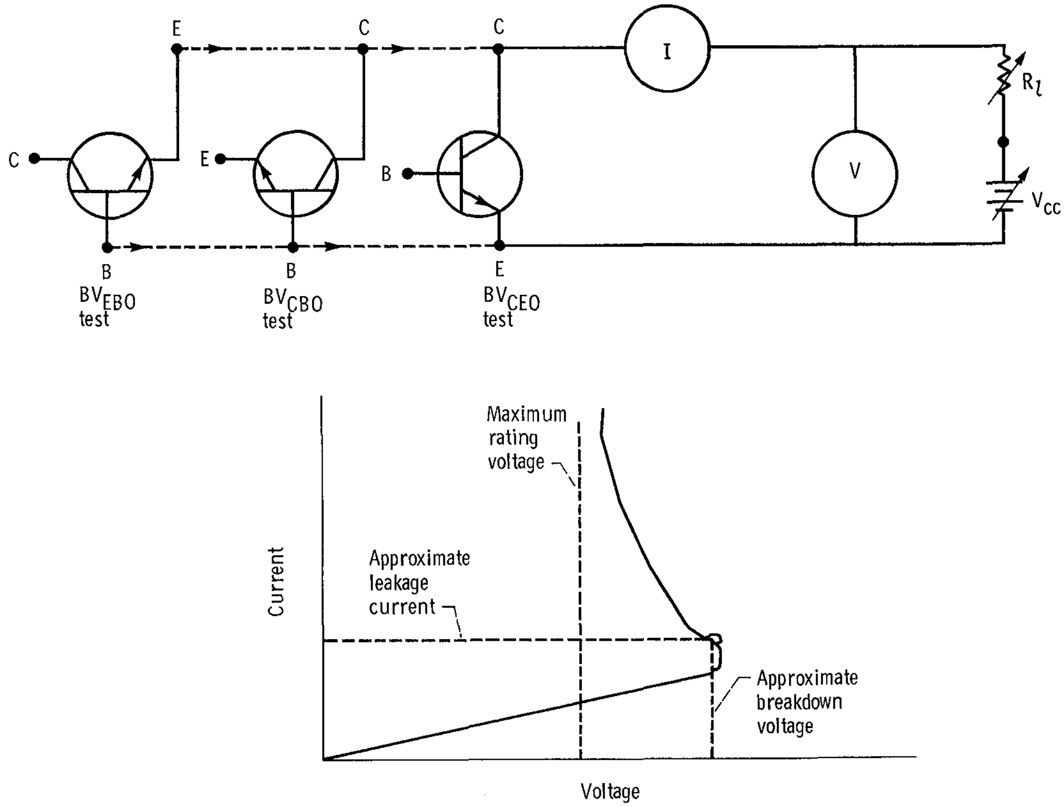

Figure 6. – Simplified diagram of transistor screening test circuit.

t_f fall time, or time for output collector current to go from 90 to 10 percent of its saturation value

h_{FE} current gain, or the ratio of output collector current over input base current

Step-by-step procedures for these tests are given in appendix B.

Using the PATTS

Up to this point we have described the PATTS in general terms. Here a specific npn power transistor is put through a test sequence to illustrate how the test data can be presented. The test results for three base-drive currents are compared; the rest of the test conditions remain unchanged for all cases. A constant data input listing, a test circuit diagram, dynamic switching waveforms, and dynamic switching characteristics are presented for each case.

Constant Data Input Listing

Table I lists the constant data input for all three cases. Note that forward and reverse base-drive currents are different for each case.

Test Circuit Diagram

A simplified test circuit diagram (fig. 3) is used as a reference for all tests. The circuit component values are given in table I.

Dynamic Switching Waveforms

Dynamic switching waveforms are presented and compared in figures 7 to 9 for three base-drive currents:

Case 1: low forward and zero reverse base-drive current
Case 2: low forward and moderate reverse base-drive current
Case 3: high forward and moderate reverse base-drive current

The notations for these waveforms on the computer output display are listed in the following order:

I_{b1} base-drive current, A
I_c collector current, A
V_{ce} collector-emitter voltage, V
Pwr power loss, W
Erg energy loss, J

and Z indicates a vertical zero reference level (attached at the end of each waveform notation) and VSF denotes a vertical scale factor or unit per division in the mks system.

TABLE I.—CONSTANT DATA INPUT LISTING

[Cases 1, 2, and 3.]

HEADER INFORMATION
MANUFACTURER: WESTINGHOUSE/D60T753005
PART NUMBER: DEVICE 8
TEST TITLE: LOW FORWARD AND NO REVERSE BASE CURRENT
OPERATOR'S NAME: LONG V. TRUONG
TEST DATE: 7/17/85

TEST CIRCUIT COMPONENTS
D1 DIODE PART: PTC 900
D2 DIODE PART: PTC 900
$R\ell$ RESISTOR RATING: FROM 1 to 10 kW (DEPENDING ON DUTY CYCLE)
$L\ell$ INDUCTOR RATING: 23 μH, 50 A, r=0.00115
Cs CAPACITOR RATING: 0.047 μF, 800 V
Rs RESISTOR RATING: 25 Ω, 50 W
Ta AMBIENT TEMPERATURE: 25 DEGREES C
Vcc OR dc POWER SUPPLY: 600 V, 25 A PER UNIT (TWO HP MODEL 6483 IN PARALLEL)

JUNCTION BREAKDOWN VOLTAGES AND LEAKAGE CURRENTS
VCEO MAX.: 1400
ICEO MAX.: 2.0E−4
VCBO MAX.: 1400
ICBO MAX.: 2.0E−4
VEBO MAX.: 10
IEBO MAX.: 5.0E−4

CASE 1: BASE-DRIVE INFORMATION
TESTING FREQUENCY: 25 kHz
FORWARD Ib DRIVE: 3 STEPS
REVERSE Ib DRIVE: 0

CASE 2: BASE-DRIVE INFORMATION
TESTING FREQUENCY: 25 kHz
FORWARD Ib DRIVE: 3 STEPS
REVERSE Ib DRIVE: 1 STEP

CASE 3: BASE-DRIVE INFORMATION
TESTING FREQUENCY: 25 kHz
FORWARD Ib DRIVE: 10 STEPS
REVERSE Ib DRIVE: 1 STEP

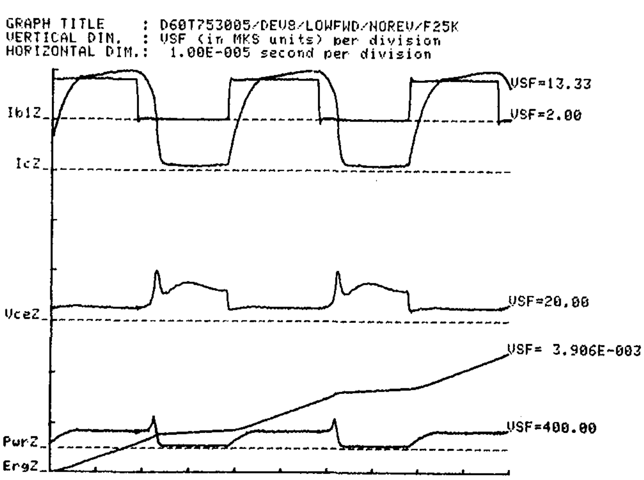

Figure 7.—Dynamic switching waveforms for case 1 (no reverse base-drive current).

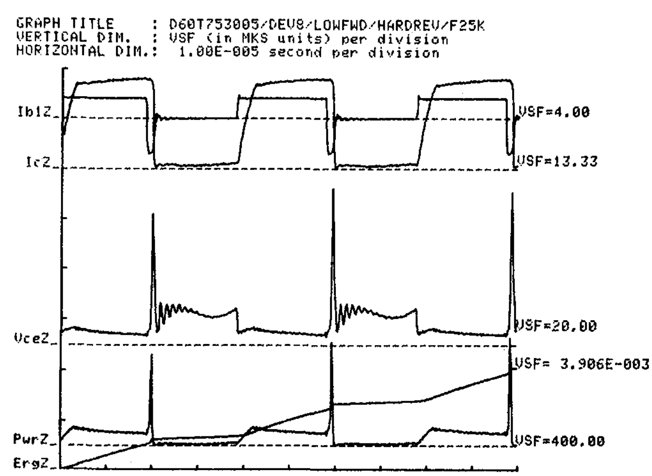

Figure 8.—Dynamic switching waveforms for case 2 (moderate reverse base-drive current).

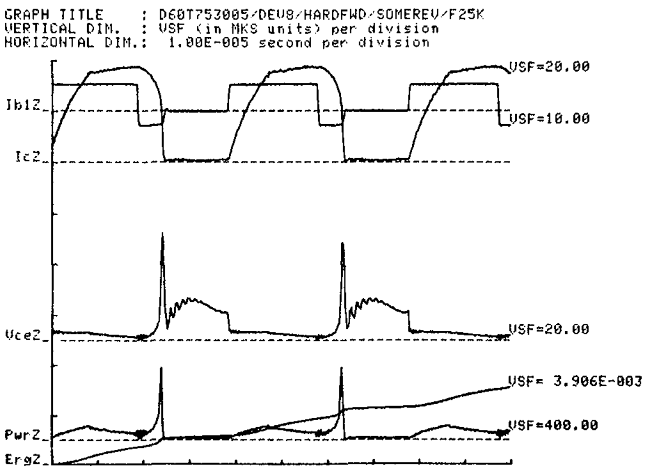

Figure 9. – Dynamic switching waveforms for case 3 (high forward base-drive current).

TABLE II. – DYNAMIC SWITCHING CHARACTERISTIC PARAMETERS

CASE 1
SWITCHING CHARACTERISTIC PARAMETERS MAXIMUM dc/STEADY STATE OF BASE(1) CURRENT: 1.67 MAXIMUM dc/STEADY STATE OF BASE(2) CURRENT: 0.00 MAXIMUM dc/STEADY STATE OF COLLECTOR CURRENT: 26.64 MINIMUM dc/STEADY STATE OF Vce (ON TIME): 4.48 FORWARD CURRENT GAIN (Ic/Ib1): 16.00 DELAY TIME: 4.81E−007 RISE TIME: 5.66E−006 STORAGE TIME: 2.229E−006 FALL TIME: 3.08E−006 ON TIME: 6.14E−006 OFF TIME: 5.36E−006
CASE 2
SWITCHING CHARACTERISTIC PARAMETERS MAXIMUM dc/STEADY STATE OF BASE(1) CURRENT: 1.67 MAXIMUM dc/STEADY STATE OF BASE(2) CURRENT: 0.00 MAXIMUM dc/STEADY STATE OF COLLECTOR CURRENT: 24.16 MINIMUM dc/STEADY STATE OF Vce (ON TIME): 3.92 FORWARD CURRENT GAIN (Ic/Ib1): 14.48 DELAY TIME: 7.17E−007 RISE TIME: 3.05E−006 STORAGE TIME: 1.40E−006 FALL TIME: 5.28E−006 ON TIME: 3.76E−006 OFF TIME: 1.93E−006
CASE 3
SWITCHING CHARACTERISTIC PARAMETERS MAXIMUM dc/STEADY STATE OF BASE(1) CURRENT: 5.35 MAXIMUM dc/STEADY STATE OF BASE(2) CURRENT: 0.00 MAXIMUM dc/STEADY STATE OF COLLECTOR CURRENT: 37.64 MINIMUM dc/STEADY STATE OF Vce (ON TIME): 0.92 FORWARD CURRENT GAIN (Ic/Ib1): 7.04 DELAY TIME: 8.57E−007 RISE TIME: 7.08E−006 STORAGE TIME: 3.07E−006 FALL TIME: 2.84E−006 ON TIME: 7.94E−006 OFF TIME: 5.91E−006

Dynamic Switching Characteristics

Table II shows the dynamic switching characteristic parameters for the three cases. For moderate reverse base-drive current (case 2) the storage time was 0.887 sec less than that for zero reverse base-drive current (case 1). This shorter time interval during the device turnoff means that a higher design frequency can be achieved for a specific transistor by adding a hard negative base drive. In practice, the reverse base-drive current application can damage the device if the applied emitter-base voltage (needed for negative current) exceeds its maximum voltage rating. Typically this voltage is about 6 to 12 V for most npn power transistors. Refer to table I for the emitter-base breakdown voltage (VEBO MAX.) of the Westinghouse D60T753005 power transistor.

Another critical effect demonstrated in this test is the collector-emitter spike voltage generated during the device turnoff. This spike voltage is directly proportional to the reverse base-drive current and the value of circuit inductance. The illustrated V_{ce} waveforms for cases 1 and 2 (figs. 7 and 8) show roughly a 40-V difference in peak collector-emitter voltage. This spike voltage creates a fairly high peak instantaneous power ($p = V_{ce} I_c$) that could exceed the maximum rated power and damage the device. The illustrated Pwr waveforms (figs. 8 and 9) show approximately a 600-W difference in peak power output.

The V_{ce} waveforms for cases 2 and 3 (figs. 8 and 9) show that the higher forward (positive) pulse base-drive currents used in case 3 enabled the transistor to reach its saturation region more quickly. This shorter time to saturation means lower power dissipation during turn-on. From the table II the values of V_{ce} (on time) are 4.48 V for case 1, 3.92 V for case 2, but only 0.9 V for case 3.

These comparisons demonstrate how a power transistor's instantaneous power loss is affected by the base-drive current. Because of the uniqueness and accurate repeatability of the tests on each device, the PATTS can sensitively monitor transistor characteristics as a function of frequency, load variations, snubber and other protection circuits, temperature, and various forms and levels of harmful radiation. Transistors of the same or different types or the same or different manufacturers can be easily compared.

Concluding Remarks

The new programmable, automated transistor test system (PATTS) is fast, accurate, reproducible, and very flexible. Input processing, test procedures, and data manipulation are guided and controlled by the executive software. Since the system is operator interactive, however, the test parameters may be selected uniquely for each transistor. The automatic control virtually eliminates operator error.

PATTS enables accurate, dynamic data to be taken on each transistor for comparison with other transistors of the same or different manufacturers or of the same or different types. The dynamic switching waveforms and other numerical test data on individual transistors can be used for modeling and experimental analysis and as critical information for circuit designers. The accuracy and repeatability of the PATTS enable objective monitoring of incremental changes in transistor characteristics due to radiation, temperature excursions, mechanical shock, and vibration.

The PATTS with its modern equipment, tailored design, and computer-interactive operation significantly improves the testing of power transistors. Since the system is automated, it is truly a time saver for massive data collection, catalog storage, comprehensive analysis, and final data presentation. The system is also designed to guard against unnecessary operator errors and frustration.

Further information about the system can be found in the appendixes and in the literature listed in the bibliography or by directly contacting the authors.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, November 18, 1985

Appendix A
Screening Tests

V_{CEO} Test

The collector-emitter breakdown voltage with open base can be determined by using the tests for I_{CEO} and BV_{CEO} from the Tektronix 576 Curve Tracer Instruction Manual (obtainable from the manufacturer):

Do the following steps with the power off:

(1) Put the transistor on the test fixture, using the transistor adapter and the protective box.

(2) Set the maximum-peak-voltage switch slightly above the BV_{CEO} value given on the manufacturing data sheet.

(3) Set the maximum-peak-power switch below the value given on the manufacturing data sheet.

(4) Set the variable-collector-supply potentiometer to zero.

(5) Set the mode switch to normal.

(6) Set the polarity switch to npn for an npn transistor and to pnp for a pnp transistor.

(7) Set the left-off-right switch to the off position.

(8) Set the terminal-selector switch to the base-term-open position (or EXT).

(9) Set the vertical-current-per-division switch to the appropriate value.

(10) Set the horizontal-voltage-per-division switch to the appropriate value.

(11) Set the display-offset switch to normal (off).

Do the following steps with the power on:

(1) Turn the power switch to the on position.

(2) Adjust the vertical and horizontal switches to set reference zero and make sure the display-inverted pushbutton is not pushed.

(3) Adjust the intensity and focus switches if needed.

(4) Turn the left-off-right switch to the position that matches the location of your transistor on the test fixture. Power now is applied to the transistor.

(5) Turn the variable-collector-supply potentiometer slowly clockwise (to increase V_{CEO}) until the breakover point is reached. Refer to figure 3 for determination of BV_{CEO} and V_{CEO}.

(6) Adjust the vertical current-per-division and horizontal voltage-per-division switches for maximum resolution of the display curve.

I_{CEO} Test

The leakage current can be found by the previous test, except that the mode switch is set to leakage (emitter current).

BV_{CBO} and I_{CBO} Tests

Collector-base breakdown voltage and collector-base leakage current with the emitter open are measured in the same way as BV_{CEO} and I_{CEO} except that the terminal-selector switch is set to the emitter-term-open position (or EXT).

BV_{EBO} and I_{EBO} Tests

Emitter-base breakdown voltage and emitter-base leakage current with the collector open are measured in the same way as BV_{CBO} and I_{CBO} except that the device terminals are inverted in the device testing socket (the collector lead in the emitter terminal of the socket and the emitter lead in the collector terminal).

Appendix B
Characteristic Tests

Initial Autoload Sequence

The initial autoload sequence proceeds as follows:

(1) Apply power to the system

(a) Set up the test circuit (fig. 3)

(b) Turn on all peripheral devices

(c) Turn on the desktop computer (controller)

(2) Set the system clock

(a) Insert the npn autoload tape into the system's tape drive and press the autoload key.

(b) The system responds with

PLEASE ENTER THE DATE:
(EX.: 15-AUG-52): 22-FEB-85
PLEASE ENTER THE TIME:
(EX.: 12:30:45 PM): 09:30:00 AM

The system clock indicator on the master disk drive (disk drive 0) should be off at this time.

(3) Display the tape directory: After step 2(b) the terminal screen should be clear, and the npn autoload tape directory appears on the screen as follows:

TRANSISTOR TEST EXECUTIVE TAPE

FILE #	CONTENTS
1	SYSCLOCK/TAPE LISTING/AUTO LOAD
2	NPN TRANSISTOR TEST UDK'S AND MENU
3	NPN USER-DEFINABLE KEYS (UDK'S)
4	NPN TRANSISTOR TEST MENU
5	HELP/INTRODUCTION
6	BASE-DRIVE REMOTE OPERATION
7	INITIALIZATION
8	CONSTANT INPUT: HEADER INFORMATION DEVICE RATING TEST CIRCUIT PARAMETERS
9	TRANSISTOR TEST PROCESSING: DYNAMIC WAVEFORMS DC MEASUREMENTS
10	DATA FILE MANAGEMENT: CREATE–SAVE–LOAD–MODIFY (DISK, TAPE, AND EXTENDED MEMORY)
11	TEST OUTPUT PACKAGE: NUMERICAL DATA LISTING CIRCUIT DIAGRAM PLOTTING WAVEFORMS
12	TERMINATION ROUTINE

PRESS RETURN KEY WHEN YOU ARE READY

The transistor test executive tape is a backup tape (there is also a backup disk) for all of the program modules that reside in the extended memory area on unit 4 (fig. 5). The return key is pressed at this time to continue. The terminal screen will clear and update as shown here:

NPN TEST PROGRAMS WILL BE EXECUTED
FROM UNIT 4
UNIT 4 DIRECTORY:
NPNOUTPUT8
NPNTERM9
NPNSTOCK
NPNMENU
NPNDEMO
NPNHELP2
NPNDATA1
NPNUDK0
NPNBASEDR3
NPNCONST5
NPNXSFER10
NPNGAIN11
NPNPRINT41
NPNTAPEDIR
NPNMENU1
NPNTEST6
NPNFILE7
NPNCHG
NPNINIT4
END OF UNIT 4 DIRECTORY

ATTENTION:
IF UNIT 4 DIRECTORY WAS EMPTY, PLEASE PRESS KEY "1" TO RELOAD THE SOFTWARE (FROM TAPE TO UNIT 4), OR PRESS ANY OTHER KEY TO OBTAIN THE NPN TRANSISTOR TEST OR MAIN MENU

Not all of the program modules listed above are used during the test. The program modules that will be used during the test (fig. 5) are

NPNUDK0	control program module
NPNMENU1	main menu
NPNHELP2	help/introduction
NPNBASEDR3	base-drive remote control
NPNINIT4	initialization
NPNCONST5	constant data input
NPNTEST6	transistor test processing
NPNFILE7	file management
NPNOUTPUT8	output package
NPNTERM9	termination routine

The rest of the npn program modules are used for other purposes.

(4) Autoload the system software: The system software can be loaded automatically, from tape to unit 4, by pressing key 1 from step 3 if and only if the unit 4 directory is empty.

(5) Obtain the main menu: The main menu is obtained by pressing any key (except key 1) from step 3. The main menu is a short form of the executive tape directory. It will be used throughout the test procedure.

```
        NPN TRANSISTOR TEST MENU
UDK'S:  FOR
--------------------------------------------
  1     NPN TRANSISTOR TEST MAIN MENU
  2     HELP
  3     BASE-DRIVE REMOTE OPERATION
  4     INITIALIZATION
  5     CONSTANT DATA INPUTS
  6     TRANSISTOR TEST PROCESSING
  7     FILE MANAGEMENT
  8     OUTPUT PACKAGE
  9     TERMINATION
--------------------------------------------
USE USER-DEFINABLE KEYS
SELECT YOUR OPTION
```

All of the program modules are assumed to be present in unit 4. The initial autoload sequence can be bypassed by typing the following commands:

```
CALL "SETTIME," "DO_MON_YY HH:MM:SS"
UNIT 4
OLD "NPNMENU"
RUN
```

where

DO	date of month, including leading zero
MON	month of year, first three characters
YY	year, last two digits only
HH	hour, including leading zero
MM	minute, including leading zero
SS	second, including leading zero

Program Modules

The initial autoload sequence procedure must be completed before running any of the program modules.

Main menu program module. – The main menu displays all of the PATTS options. It also serves as a key point to transfer system control to the control program module after each selection is made from its menu.

Execution: To obtain the main menu, simply press key 1 from the user-definable key (UDK) board. (See above.)

Options: All of the options are listed on the main menu. Each option is a specific program module. The program modules are described in the remainder of this appendix.

Limitations/restrictions: When collecting test data on a device under test for the first time, options should be selected in the sequence listed on the main menu.

Help/introduction program module. – This program module helps the operator get acquainted with the PATTS and assists him or her in case of operational difficulties. Each program module is described briefly in this help file.

Execution: Obtain the main menu and then select option 2 by pressing UDK 2. The program module starts as shown here:

```
      HELP FILE OR INTRODUCTION OF PATTS

1.FIRST TEST DATA RUN ON DEVICE UNDER TEST

  FROM MAIN MENU RUN THE FOLLOWING
  PROGRAM MODULES IN THIS SEQUENCE:

    - BASE-DRIVE REMOTE OPERATION, FOR
      REMOTE CONTROL ONLY
    - INITIALIZATION
    - CONSTANT DATA INPUT
    - TRANSISTOR TEST PROCESSING
    - FILE MANAGEMENT
    - OUTPUT PACKAGE
    - TERMINATION (OPTION)

2.LOAD DATA FROM TAPE, DISK, OR UNIT 4 FOR
  OUTPUT

  FROM MAIN MENU RUN THE FOLLOWING
  PROGRAM MODULES IN THIS SEQUENCE:

    - INITIALIZATION
    - FILE MANAGEMENT
    - OUTPUT PACKAGE
    - TERMINATION (OPTION)

STEP-BY-STEP INSTRUCTIONS ARE AVAILABLE IN
EACH PROGRAM MODULE

PRESS RETURN KEY WHEN YOU ARE READY


DESCRIPTION OF THE PROGRAM MODULES (PM'S)

  (PRESS HOME PAGE KEY TO SEE NEXT PAGE)

MAIN MENU:
THIS PM IS USED TO DISPLAY THE PATTS OPTIONS.
IT'LL TRANSFER THE SYSTEM CONTROL TO THE
CONTROL PM AFTER EACH SELECTION IS MADE
FROM ITS MENU.
```

HELP/INTRODUCTION:
THIS PM IS USED TO ACQUAINT THE OPERATOR WITH THE PATTS.

BASE-DRIVE REMOTE OPERATION:
THIS PM IS USED TO SET UP THE BASE CURRENT OR CURRENTS FOR THE TRANSISTOR UNDER TEST. IT'S ALSO A "HANDSHAKING" FOR THE BASE DRIVE, THE TEKTRONIX 4052A CONTROLLER, AND THE MAINFRAME COMPUTER.

INITIALIZATION:
THIS PM IS USED TO DEFINE AND INITIALIZE ALL OF THE COMMON VARIABLES IN THE SYSTEM.

CONSTANT DATA INPUT:
THIS PM IS USED TO ENTER DATA OBTAINED FROM THE SCREENING TESTS AND TO INPUT TEST CONDITION PARAMETERS AND OTHER NECESSARY INFORMATION.

TRANSISTOR TEST PROCESSING:
THIS PM PROVIDES ALL OF THE MEASUREMENT OPTIONS FOR THE TRANSISTOR UNDER TEST.

FILE MANAGEMENT:
THIS PM IS USED TO SAVE OR RETRIEVE TEST DATA FROM DISK, TAPE, AND EXTENDED MEMORY.

OUTPUT PACKAGE:
THIS PM IS USED TO REVIEW OR OBTAIN TEST DATA AS HARD COPIES WITH OPTIONS TO CHANGE, MODIFY, AND SELECT VARIABLES FOR OUTPUT.

TERMINATION ROUTINE:
THIS PM IS USED TO CONFIRM THE TERMINATION OF THE TEST.

PRESS RETURN KEY WHEN YOU ARE READY

This program module has no options, limitations, or restrictions.

Base-drive remote control program module. – This program module is used only for remote operation of the base drive. It permits the operator to set the magnitude of the base-drive current independently for either positive or negative values. It also provides a "handshaking" between the base drive, the Tektronix 4052A desktop computer, and the mainframe computer.

Execution: Obtain the main menu and then select option 3 by pressing UDK 3. The program module starts with the following menu:

BASE-DRIVE REMOTE OPERATION MENU

PRESS	TO
0	INITIALIZE BASE-DRIVE UNIT
1.0	DISABLE BASE-DRIVE UNIT
1.1	ENABLE BASE-DRIVE UNIT
2.N	SET FORWARD BASE(1) CURRENT AT N(00–31)
3.M	SET REVERSE BASE(1) CURRENT AT M(00–32)
4.M	SET REVERSE BASE(2) CURRENT AT M(00–32)
5.0	DISABLE REVERSE BASE(2)
5.1	ENABLE REVERSE BASE(2)
6	EXAMINE BASE-DRIVE STATUS
7	EXIT (RETURN TO MAIN MENU)

ENTER YOUR OPTION

A desired base current can be set by using the proper options. For example, if the operator desires to start the base drive and set the magnitude of the forward and reverse current at 2 A, the following options should be selected:

Option 0	initialization
Option 1.1	turn on base (1) current
Option 2.4	set +2 A (+0.5 A/step $\times$ 4 steps)
Option 3.4	set −2 A (−0.5 A/step $\times$ 4 steps)

Other options are self-explanatory and executed in the same manner.

Options: All of the options are listed on the base-drive remote operation menu.

Limitations/restrictions: The maximum base-drive currents are divided into 32 incremental steps (options 2 to 4), approximately 0.5 A/step. The unit per step can be increased or decreased within ±25 percent by changing the external power supply voltages in the analog board (in the base drive). Overall the base-drive current should not exceed ±25 A.

Initialization program module. – This program module is used solely to set the initial values for the system common variables. It must be executed once and only once (unless the variables need to be reset) when the system is first turned on.

Execution: Obtain the main menu and then select option 4 by pressing UDK 4. The program module starts and finishes in the following way:

INITIALIZATION PROGRAM MODULE NOW IS RUNNING . . .
SYSTEM VARIABLES ARE INITIALIZED

This program module has no options, limitations, or restrictions.

Constant data input program module. – This program module registers fixed data into computer memory. These constant data include the test circuit parameters, the test conditions, the device under test rating, and other necessary information.

Execution: Obtain the main menu and then select option 5 by pressing UDK 5. The program module starts with the data listing and offers an option to either change the data or input new data.

CONSTANT DATA INPUT LISTING

HEADER INFORMATION:
01.MANUFACTURER/PART #: WESTINGHOUSE/D60T753005
02.DEVICE NUMBER: DEVICE #8
03.TITLE/REMARKS: HARD FORWARD AND SOME REVERSE BASE CURRENT
04.OPERATOR'S NAME: LONG V. TRUONG
05.TEST DATE: 7/17/85
SUPPORTED TEST CIRCUIT PARAMETERS (USE OUTPUT PROGRESS TO SEE CIRCUIT DIAGRAM):
06.LOAD DIODE D1: PTC 900
07.SNUBBER DIODE D2: PTC 900
08.LOAD RESISTOR $R\ell$: FROM 1 to 10 kW (DEPENDING ON DUTY CYCLE)
09.LOAD INDUCTOR $L\ell$: 23 μH, 50 A, r=0.00115
10.SNUBBER CAPACITOR Cs: 0.047 μF, 800 V
11.SNUBBER RESISTOR Rs: 25 Ω, 50 W
12.AMBIENT TEMPERATURE Ta: 25 DEGREES C
13.DC SUPPLY VOLTAGE Vcc: 600 V, 25 A PER UNIT (TWO HP MODEL 6483 IN PARALLEL) MAXIMUM DEVICE RATING:
14.VCEO=1400
15.ICEO=2.0E−4
16.VCBO=1400
17.ICBO=2.0E−4
18.VEBO=10
19.IEBO=5.0E−4

BASE-DRIVE INFORMATION:
20.FREQUENCY=25 kHz
21.FORWARD Ib=10
22.REVERSE Ib=1

ENTER ITEM # YOU WISH TO CHANGE, (0=MAIN MENU): 0

Options: All of the constant data inputs can be read in from the data file instead of registered from the terminal keyboard. To accomplish this, the file management program module must be executed prior to this program module. The file management program module is described in detail later in this appendix.

Limitations/restrictions: The inputs of items 1 to 13 and 20 to 22 are limited to 50 characters per item, but they can be entered in free style (i.e., in any alphanumeric combination). The inputs of items 14 to 19 must be numerical.

Transistor test processing program module. – This program module provides all of the measurement options for the transistor under test. These options are listed on the menu and discussed in detail here.

Execution: Obtain the main menu and then select option 6 by pressing UDK 6. The program module starts with the input requirement:

TURN ON YOUR SCOPE
PRESS ID KEY ON SCOPE PANEL
READ SCOPE ADDRESS NUMBER FROM SCOPE SCREEN
ENTER SCOPE ADDRESS NUMBER HERE →: 2

After the scope address is entered, the program module menu should appear:

TRANSISTOR TEST PROCESSING MENU

PRESS:	FOR:	SCOPE MEMORY
01	HELP	
02	TEST EQUIPMENT POWER-ON SEQUENCE	
03	SETTING BASE(1)&(2) CURRENT WAVEFORMS	
04	BASE(1) CURRENT WAVEFORM PROCESSING	2WFM
05	BASE(2) CURRENT WAVEFORM PROCESSING	3WFM
06	COLLECTOR CURRENT WAVEFORM PROCESSING	4WFM
07	COLLECTOR-EMITTER VOLTAGE PROCESSING	5WFM
08	DELAY AND RISE-TIME MEASUREMENTS	2,4→6&7WFM
09	STORAGE AND FALL-TIME MEASUREMENTS	2,4→6&7WFM
10	STEADY-STATE VALUES OF Ib1, Ib2, Ic, AND Vce	
11	MAIN MENU	
12	RESTART OF THIS PROGRAM	

? SELECT YOUR OPTION

Options: This program module has seven transistor test measurement options (4 to 10) and five supplementary options (1 to 3, 11, and 12). These options are as follows:

(1) HELP INFORMATION. From the program module menu select option 1 by pressing first key 1 and then the return key. The following information should appear:

HELP INFORMATION

-THIS PROGRAM MODULE OPTION CAN BE RUN INDEPENDENTLY AND REPEATEDLY. THE EXCEPTION IS THAT OPTIONS 4 TO 7 MUST BE EXECUTED FIRST, ON THE FIRST RUN.

-OPTIONS 1 TO 3 PROVIDE HELP INFORMATION AND RESTRICTIONS.

-WORK YOUR WAY THROUGH OPTIONS 4 TO 10. SKIP OPTION 5 IF THE DEVICE UNDER TEST IS A SINGLE-BASE TRANSISTOR.

-OPTION 11 WILL TAKE YOU BACK TO THE MAIN MENU.

-USE OPTIONS 6 AND 7 ON THE MAIN MENU TO SAVE AND OUTPUT YOUR TEST DATA.

PRESS RETURN KEY WHEN YOU ARE READY

(2) TEST EQUIPMENT POWER-ON SEQUENCE. This option serves as a reminder to power on the remainder of the test equipment. From the program module menu select option 2 by pressing first key 2 and then the return key. The program module should display the messages in the following form:

TEST EQUIPMENT POWER-ON SEQUENCE

PLEASE TURN ON THE FOLLOWING EQUIPMENT IF IT HAS NOT BEEN TURNED ON AND ALLOW 15 MINUTES TO WARM UP:

- BASE DRIVE AND ASSOCIATED POWER SUPPLIES
- HARD-COPY UNIT
- PRINTER

NOTES: SCOPE AND DISK DRIVE UNITS SHOULD BE ALREADY ON

PRESS RETURN KEY WHEN YOU ARE READY

(3) ESTABLISH BASE (1) AND BASE (2) CURRENT WAVEFORMS. This option provides some helpful information with regard to establishing the base-drive currents. This step is required only if the base-drive currents were not previously set. From the program module menu select option 3 by pressing first key 3 and then the return key. The program module should display the following information:

HELP INFORMATION FOR SETTING UP BASE-DRIVE CURRENT

-USE ONLY BASE(1) CURRENT FOR A SINGLE-BASE-TERMINAL TRANSISTOR

-USE BOTH BASES(1) AND (2) FOR A DARLINGTON OR DOUBLE-BASE-TERMINAL TRANSISTOR

-FROM EXTERNAL POWER SUPPLY TO THE BASE DRIVE, DO THE FOLLOWING:

- SET THE POSITIVE SUPPLY VOLTAGE TO 15 V
- SET THE NEGATIVE SUPPLY VOLTAGE FOR LESS THAN THE MAXIMUM ABSOLUTE VALUE OF V_{BEO}, TYPICALLY FROM -4 TO -7 V

-SET BASE CURRENT WAVEFORM: SUPPOSE WE WANT A PULSE TRAIN OF 16 PULSES AT 20 kHz AND 5% OF DUTY CYCLE FOR BASE-DRIVE CURRENT WAVEFORM. FROM THE WAVEFORM GENERATORS (FG 501A AND 502) DO THE FOLLOWING:

- FROM FG 502, SET OPERATING PULSES AT APPROX 50 μs/CYCLE (20 kHZ)
- FROM FG 501A, SET ENVELOPE PULSES AT APPROX 8 ms/CYCLE ($50\times16\times10$ μs) THEN ADJUST THE WAVEFORM FOR 10% OF DUTY CYCLE

THE DESIRED WAVEFORM IS A PRODUCT OF THE OPERATING AND ENVELOPE WAVEFORMS. ITS MAGNITUDE CAN BE SET MANUALLY OR REMOTELY CONTROLLED BY THE BASE-DRIVE REMOTE OPERATION PROGRAM MODULE.

A BASE CURRENT OF DIFFERENT FREQUENCY, DUTY CYCLE, AND NUMBER OF PULSES CAN BE PRODUCED IN THE SAME MANNER.

PRESS RETURN KEY WHEN YOU ARE READY

(4) BASE (1) CURRENT WAVEFORM PROCESSING. This option must be run to digitize and store the base (1) current waveform in the scope memory. This waveform is eventually transferred to the controller for storage after its magnitude is converted to amperes and verified by the operator. From the program module menu select option 4 by pressing first key 4 and then the return key. You are now in option 4 processing:

BASE (1) CURRENT WAVEFORM PROCESSING

-512 DIGITIZING POINTS PER WAVEFORM
-SCOPE CANNOT BE SET AT CHOP, ADD, OR ALT MODE
-WAVEFORM MUST BE STABLE

ENTER AVERAGING NUMBER (50,30,25,20,10,...) WHEN YOU ARE READY: 20
WAVEFORM IS BEING TRANFERRED ...

PLEASE CHECK YOUR PROBE FOR ATTENUATION FACTOR. SOME PROBES ARE AUTOMATICALLY ADJUSTABLE WITH VERTICAL SCALE FACTOR (P6101...), BUT SOME PROBES ARE NOT (P60007..)
DO YOU NEED TO CORRECT VERTICAL SCALE FACTOR? (Y/N): Y
ENTER YOUR PROBE ATTENUATION FACTOR: 1
IS THIS A CURRENT WAVEFORM TRANSFER? (Y/N): Y
ENTER NUMBER OF VOLT(S) PER AMPERE RATIO: 10E−3

VERTICAL UNIT PER DIVISION=5
IS IT CORRECT? (Y/N): N
ENTER YOUR PROBE ATTENUATION FACTOR: 1
IS THIS A CURRENT WAVEFORM TRANSFER? (Y/N): Y
ENTER NUMBER OF VOLT(S) PER AMPERE RATIO: 50E−3

VERTICAL UNIT PER DIVISION=1
IS IT CORRECT? (Y/N): Y

SAVING BASE(1) CURRENT WAVEFORM IN 2WFM SCOPE MEMORY...

A typical waveform of base (1) current displayed on the scope screen after the digitizing period is shown in figure 10.

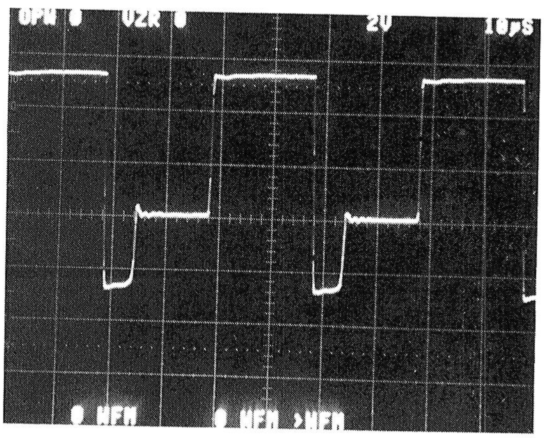

Figure 10.—Base (1) current waveform.

(5 to 7) These options are repeated from the same routine as option 4, except that here the base (2) current (only for a double-base transistor or Darlington), collector, and collector-emitter voltage waveforms are saved. Typical waveforms of collector current and collector-emitter voltage after the digitizing period are shown in figures 11 and 12.

(8) DELAY AND RISE-TIME MEASUREMENTS. This option measures the delay and rise times of the device under test. A cursor measurement method is applied in all timing measurements for more accurate data. From the program module menu select option 8 by pressing first key 8 and then the return key. You are now in option 8 processing:

DELAY AND RISE-TIME MEASUREMENTS

VERTICAL AND HORIZONTAL EXPANSION OF Ib AND Ic WAVEFORMS BETWEEN 2 CURSORS:
•USE ⟨CRS1⟩ and ⟨CRS2⟩ KEYS FROM TEK7854 OSCILLOSCOPE

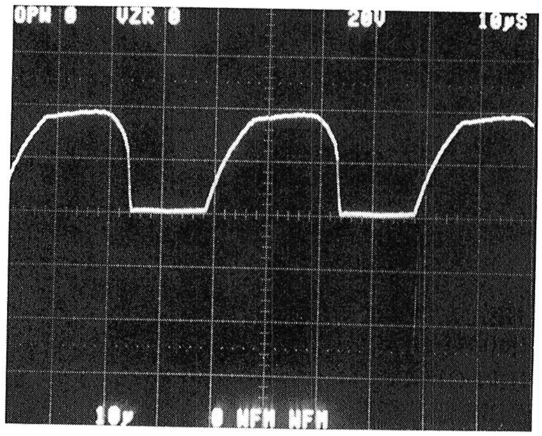

Figure 11.—Collector current waveform.

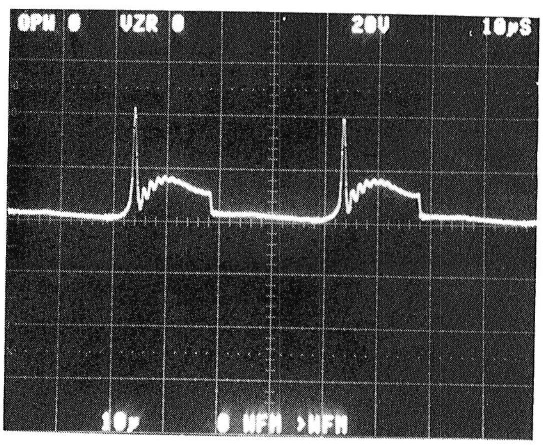

Figure 12.—Collector-emitter voltage waveform.

•SELECT A PORTION OF WAVEFORM TO EXPAND FOR MEASUREMENTS
PRESS RETURN KEY WHEN YOU ARE READY

Figures 13 and 14 show the scope displays of base (1) and collector currents before and after finishing the preceding instructions.

The option procedure continues with a second message as follows:

YOU SHOULD HAVE A RISING EDGE OF BASE AND COLLECTOR CURRENT WAVEFORMS ON SCOPE'S DISPLAY FOR DELAY AND RISE-TIME MEASUREMENTS. IF NOT, ANSWER NO TO THE QUESTION BELOW.
IS IT O.K. TO GO ON? (Y/N): Y

In this example, referring to figure 14, a "yes" answer would be appropriate. If the answer is "no," the program module automatically returns to its menu. Then selecting option 8 again gives the operator another try to set the proper interval between the two cursors. After a "yes" answer the program module continues with the following instruction:

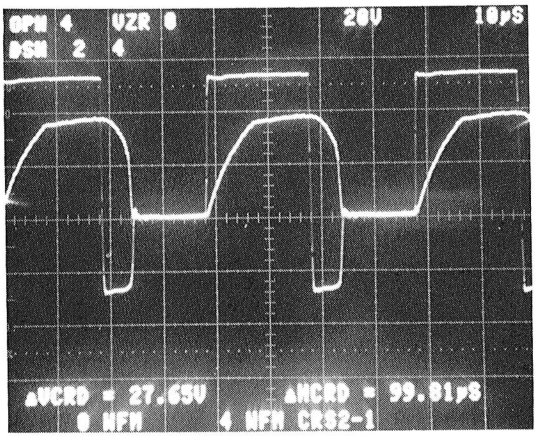

Figure 13.—Base (1) and collector current waveforms before last step of instruction.

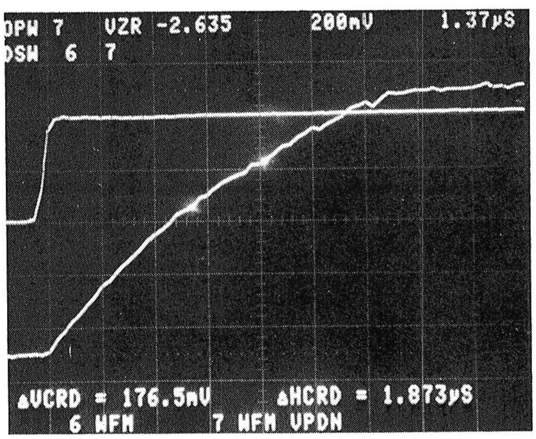

Figure 14.—Base (1) and collector current waveforms after last step of instruction.

DELAY TIME WILL BE MEASURED FROM WHERE THE BASE CURRENT WAVEFORM STARTS TO RISE UNTIL 10% OF COLLECTOR CURRENT WAVEFORM:
•USE VERTICAL POSITION KEYS FROM WAVEFORM CALCULATOR KEYBOARD TO MOVE WAVEFORM IN BETWEEN 0 AND 100% LEVELS
•MOVE CURSOR 1 AT POSITION AT WHICH BASE CURRENT WAVEFORM STARTS TO RISE AND CURSOR 2 AT 10% OF COLLECTOR CURRENT WAVEFORM
PRESS RETURN KEY WHEN YOU ARE READY

Upon completion of this instruction, the delay time is transferred from the scope to the controller for storage after the accuracy is verified with the operator in the following manner:

CHECK AND VERIFY THE DELAY TIME IS: 7.759E−7
IS IT CORRECT? (Y/N): Y

This number should be the same as the number shown on the scope screen (ΔHCRD=775.9 ns). See figure 15.

The program module continues with the last instruction to measure the rise time:

NOW SET CURSOR 1 AT 10% LEVEL AND CURSOR 2 AT 90% LEVEL TO MEASURE THE RISE TIME
PRESS RETURN KEY WHEN YOU ARE READY

After this instruction has been followed, the rise time is transferred and saved in the computer memory or the data bank as in the delay-time measurement process. Again the verifying message appears:

CHECK AND VERIFY RISE TIME IS: 7.171E−6
IS IT CORRECT? (Y/N): Y

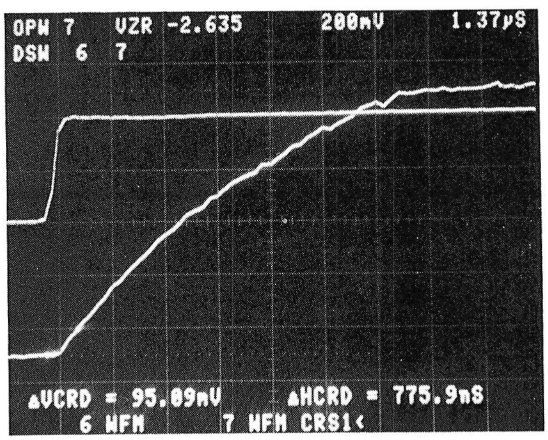

Figure 15.—Delay time (time interval between two cursors): ΔHCRD=775.9 ns.

See figure 16 for illustration:

(9) STORAGE AND FALL-TIME MEASUREMENTS. The operation of this option is similar to that of option 8, except that the proper falling portions of the base (1) and collector current waveforms must be selected. Therefore an illustration is not necessary here. However, a scope display resulting from proper selection of the falling portions of the base (1) and collector current waveforms is shown in figure 17 for reference.

(10) GAIN MEASUREMENTS. Gain measurements can be made in two ways, manually or automatically. In the manual procedure the operator is asked to enter the approximate values of the base (1) and collector currents, which are read directly from the scope. The automatic method will read out these numbers automatically from the scope memory after smoothing the related current waveforms. This waveform-smoothing action is designed to eliminate the transient effects on the actual waveforms, so that only the free or steady-state values of the waveforms will be read for this gain measurement.

From the program module select option 10 by pressing first key 10 and then the return key. The first message received is

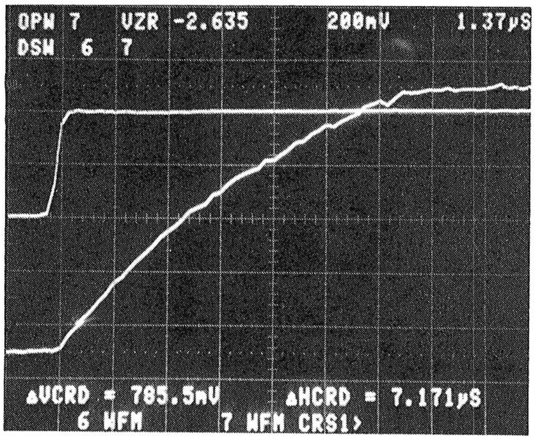

Figure 16. – Rise time (time interval between two cursors): ΔHCRD=7.171 μs.

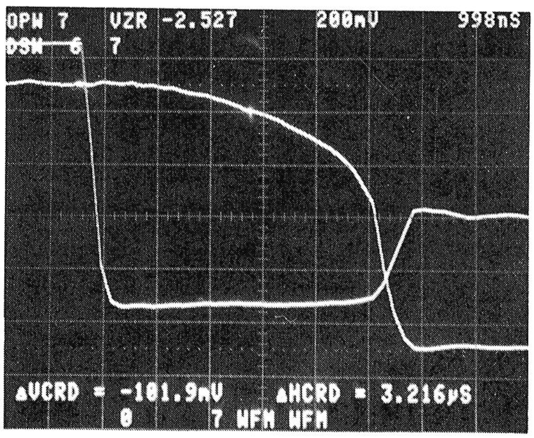

Figure 17. – Falling portions of base (1) and collector current waveforms.

DC/STEADY STATE MEASUREMENTS OF Ib1, Ib2, Ic, AND Vce
AUTO OR MANUAL? (A/M): A

Enter "A" for automatic or "M" for manual measurement. The manual measurement is straightforward; therefore its illustration is not necessary here. In the automatic calculation method, first the current waveforms will be smoothed out and then their dc or steady-state values will be located automatically by the program module. To utilize this smoothing process, the minimum point of V_{ce} or the approximate value of V_{ce} (on time) is also located. If automatic measurement is selected, the program module will respond with the first message and a request for input.

AUTO. DC/STEADY STATE MEASUREMENTS OF Ib1, Ib2, Ic, AND Vce

NOTE:
THIS CALCULATION IS BASED ON THE MAXIMUM AND MINIMUM STEADY-STATE VALUES OF THE WAVEFORMS (AFTER SMOOTHING)

DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): Y

After several times of smoothing the waveform, the operator should see the base (1) current waveform on the scope display as shown in figure 18. The smoothing procedure is repeated for base (2) (if any) collector current and collector-emitter voltage waveforms in the following manner:

DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ib1 WAVEFORM AGAIN ? (Y/N): N
DO YOU WANT TO "SMOOTH" Ib2 WAVEFORM AGAIN ? (Y/N): N
DO YOU WANT TO "SMOOTH" Ic WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ic WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ic WAVEFORM AGAIN ? (Y/N): Y
DO YOU WANT TO "SMOOTH" Ic WAVEFORM AGAIN ? (Y/N): N
DO YOU WANT TO "SMOOTH" Vce WAVEFORM AGAIN ? (Y/N): N

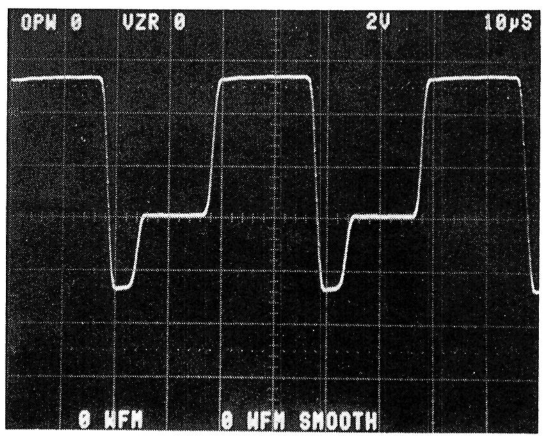

Figure 18. – Base (1) current after smoothing cycle six times.

Since the device under test in this example is a single-terminal transistor, no data for the base (2) current are collected. The collector current and collector-emitter voltage waveforms, after a series of smoothing operations, are shown in figures 19 and 20. The results of measurements and calculations are automatically printed out at the end of the procedure for verification by the operator:

CHECK AND VERIFY:
MAXIMUM BASE (1) CURRENT=5.35 A
MAXIMUM BASE (2) CURRENT=0.00 A
MAXIMUM COLLECTOR CURRENT=37.72 A
MINIMUM OR SATURATED Vce=0.92 V
GAIN (Ic/Ib1)=7.06
ARE THEY REASONABLE TO ACCEPT? (Y/N): Y

Limitations/restrictions: Error will occur if the vertical zero references for the waveforms are set improperly. Vertical zero references for all waveforms should be set at the center horizontal line on the scope screen.

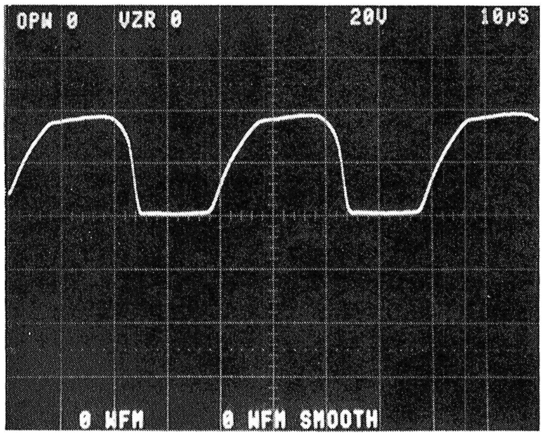

Figure 19.—Collector current waveform after smoothing.

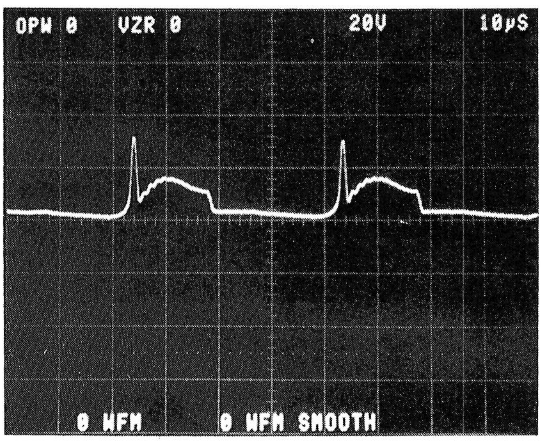

Figure 20.—Collector-emitter voltage waveform after smoothing.

File management program module.—This program module saves or loads test data from tape, disk, or extended memory (unit 4).

Execution: Obtain the main menu and then select option 7 by pressing key 7. The program module starts with the following menu:

FILE MANAGEMENT MENU

PRESS:	FOR:
1	HELP
2	MODIFY
	TAPE OPERATION:
3	SAVE
4	LOAD
	UNIT 4 OPERATION:
5	SAVE
6	LOAD
	DISK OPERATION:
7	SAVE
8	LOAD
9	MAIN MENU

SELECT YOUR OPTION

Options: The file management menu lists nine options. Two additional hidden suboptions are available before each data saving or loading process (e.g., at options 3 or 4, 5 or 6, and 7 or 8). They are the file directory and automatic file-creating features. The following examples illustrate the saving and loading of test data from the disk. Other options may be used in a similar fashion:

(1) Option 7: SAVE DATA ON DISK. Select option 7 from the program module menu, by pressing first key 7 and then the return key. Your test data will be saved in the following manner:

SAVE DATA ON DISK:

PUT OPERATING DISK INTO DISK DRIVE AND ENTER DISK DRIVE NUMBER: 0

DO YOU WANT TO CREATE A NEW FILE ? (Y/N): Y

ENTER NAME FOR THIS NEW FILE (10 CHARACTERS MAXIMUM/FIELD)
(EX.: WTH/D7ST401310/NPN001/NEW/TEST00.EDS):

TESTING

(2) Option 8: LOAD DATA FROM DISK. Select option 8 from the program module menu by pressing first key 8 and then the return key. The test data will be loaded in the following manner:

LOAD DATA FROM DISK

THIS ROUTINE WILL ERASE ALL CURRENT VARIABLES
DO YOU WANT TO CANCEL THIS EXECUTION ? (Y/N): N

PUT OPERATING DISK INTO DISK DRIVE AND ENTER DISK DRIVE NUMBER: 0
IF BASE DRIVE IS ON, ANSWER NO TO THE FOLLOWING QUESTION.
DO YOU NEED DISK DIRECTORY ASSISTANCE ? (Y/N): N

ENTER FILE NAME TO BE LOADED:
(EX: WESTINGHOU/D60T/NPN1/NORMAL/GAINVSFRE.F25K)
: TESTING

Limitations/restrictions: There is no file deletion or erase option in the program module. This option was left out intentionally to prevent the operator from accidentally erasing the test data bank. Memory clearing or file deletion can only be done by the system programmer.

Output package program module. – This program module reviews or retrieves test data as hard copies. Test data can be presented as numerical tables or graphical waveforms. In addition, many options allow the operator to change or modify the variables or select specific variables for output.

Execution: Obtain the main menu and then select option 8 by pressing UDK 8. The program starts with the following menu:

OUTPUT PACKAGE MENU

PRESS: FOR:

PRESS	FOR
01	HELP
02	LISTING TEST DATA
03	TEST CIRCUIT DIAGRAM
04	PLOTTING WAVEFORMS
05	MAIN MENU

SELECT YOUR OPTION

Options: This program module has five options.

(1) HELP. This option provides some helpful information for first-time users. Select this option from the program module menu by pressing first key 1 and then the return key. The following information should appear:

HELP INFORMATION

-RUN THIS PROGRAM MODULE TO OUTPUT YOUR CURRENT TEST DATA OR TEST DATA FROM TAPE, DISK, AND/OR EXTENDED MEMORY AREA.

-TO OUTPUT YOUR TEST DATA FROM FILE, YOU ARE REQUIRED TO RUN THE FILE MANAGEMENT PROGRAM MODULE, OPTION 7 FROM MAIN MENU, IN ORDER TO LOAD YOUR STORED TEST DATA INTO THE SYSTEM.

-ALL THE OPTIONS IN THIS PROGRAM MODULE ARE SELF-EXPLANATORY. YOU WILL FIND INSTRUCTION(S) IN EACH STEP OF THE PROCEDURE.

-HINTS:
PRESS HOME PAGE KEY WHEN THE SCREEN IS FULL TO SEE NEXT PAGE
PRESS MAKE COPY KEY AT ANY TIME TO OBTAIN A HARD COPY.

PRESS RETURN KEY WHEN YOU ARE READY FOR ACTION

(2) NUMERICAL TEST DATA LISTING. This option may be selected to review or output test data as a numerical listing. A sample printout is given here:

CONSTANT INPUT AND DC MEASUREMENT VALUES LISTING
(UNITS IN MKS SYSTEM)

PRESS HOME PAGE KEY TO SEE NEXT PAGE

HEADER INFORMATION
MANUFACTURER: WESTINGHOUSE/D60T753005
PART NUMBER: DEVICE 8
TEST TITLE: HARD FORWARD AND SOME REVERSE BASE CURRENT
OPERATOR'S NAME: LONG V. TRUONG
TEST DATE: 7/17/85

TEST CIRCUIT COMPONENTS
D1 LOAD DIODE PART: PTC 900
D2 SNUBBER DIODE PART: PTC 900
Rℓ RESISTOR RATING: FROM 1 to 10 kW (DEPENDING ON DUTY CYCLE)
Lℓ INDUCTOR RATING: 23 μH, 50 A, r=0.00115
Cs SNUBBER CAPACITOR RATING: 0.047 μF, 800 V
Rs SNUBBER RESISTOR RATING: 25 Ω, 50 W
Ta AMBIENT TEMPERATURE: 25 DEGREES C
Vcc OR dc POWER SUPPLY: 600 V, 25 A PER UNIT (TWO HP MODEL 6483 IN PARALLEL)

BASE-DRIVE INFORMATION
TESTING FREQUENCY: 25 kHZ
FORWARD Ib DRIVE: 10
REVERSE Ib DRIVE: 1

JUNCTION BREAKDOWN VOLTAGES AND LEAKAGE CURRENTS
VCEO MAX: 1400.00
ICEO MAX: 2.00E−004
VCBO MAX: 1400.00
ICBO MAX: 2.00E−004
VEBO MAX: 10.00
IEBO MAX: 5.00E−004

SWITCHING CHARACTERISTIC PARAMETERS
MAXIMUM dc/STEADY STATE OF BASE(1) CURRENT: 5.35
MAXIMUM dc/STEADY STATE OF BASE(2) CURRENT: 0.00
MAXIMUM dc/STEADY STATE OF COLLECTOR CURRENT:37.72
MINIMUM dc/STEADY STATE OF Vce (ON TIME): 0.92
FORWARD CURRENT GAIN, (Ic/Ib1)
DELAY TIME: 7.76E−007

RISE TIME: 7.17E−006
STORAGE TIME: 3.22E−006
FALL TIME: 2.77E−006
ON TIME: 7.95E−006
OFF TIME: 5.98E−006

WOULD YOU LIKE TO LIST NUMERICAL DATA OF THE WAVEFORMS? (Y/N): Y

If the answer is "yes," the program continues with a listing of the waveform numerical data (used to reconstruct the waveforms). A complete listing of the waveform numerical data is rather lengthy and unnecessary for illustration here. However, a first page of this listing is given here as an example:

BASE(1) WAVEFORM

POINT/WAVEFORM: 512
HORIZONTAL ZERO: 0
HORIZONTAL INCREMENT: 1.953E-7
VERTICAL ZERO OFFSET: 0
VERTICAL SCALE FACTOR: 2
VERTICAL ZERO LEVEL: 3
HORIZONTAL SCALE FACTOR: 1.0E-5
WAVEFORM MULTIPLE NUMBER: 0.2
CURVE:

2.6318	2.3618	2.6282	2.6221
2.6245	2.6178	2.6141	2.6202
2.6184	2.619	2.6208	2.6263
2.6282	2.641	2.6355	2.6398
2.6471	2.6526	2.6514	2.6465
2.6599	2.6556	2.6563	2.6538
2.6465	2.6569	2.6575	2.652
2.6595	2.6532	2.6611	2.6599
2.6617	2.6563	2.6654	2.6605
2.666	2.6611	2.6654	2.666
2.6697	2.6691	2.6691	2.666
2.6758	2.666	2.6648	2.6648
2.6746	2.674	2.6678	2.6733
2.6709	2.6654	2.6703	2.6697
2.6782	2.6666	2.6752	2.6746
2.6727	2.6697	2.666	2.6733
2.6758	2.6782	2.6721	2.6758
2.677	2.6733	2.6733	2.6691
2.6697	2.6678	2.6752	2.6807
2.6691	2.6752	2.674	2.6678

(3) TEST CIRCUIT DIAGRAM. This option draws and copies the test circuit diagram. The circuit component values are listed in the previous option. A computer sketch of the circuit diagram is shown in figure 3.

(4) DYNAMIC SWITCHING WAVEFORMS. This option may be selected to obtain an output in graphical waveforms. To run this option from the program module menu, press first key 4 and then the return key. A submenu for the plotting arrangement of these waveform should appear as

PLOTTING WAVEFORM(S) OPTIONS

PRESS:	FOR:
01	SELECTING WAVEFORM(S) TO PLOT
02	LABELING/TITLING YOUR GRAPH
03	PLOTTING SELECTED WAVEFORM(S)
04	MODIFYING WAVEFORM(S)
05	RETURNING TO OUTPUT PACKAGE MENU

ENTER YOUR OPTION: 1

To select waveforms to plot, choose option 1 from the plotting waveform options (PWO's) menu:

SELECTING WAVEFORM(S) TO PLOT
BASE(1) CURRENT WAVEFORM? (YES=1, NO=0): 1
BASE(2) CURRENT WAVEFORM? (YES=2, NO=0): 0
COLLECTOR CURRENT WAVEFORM?
(YES=3, NO=0): 3
COLLECTOR-EMITTER VOLTAGE WAVEFORM?
(YES=4, NO=0): 4
POWER (LOSS) WAVEFORM? (YES=5, NO=0): 5
ENERGY (LOSS) WAVEFORM? (YES=6, NO=0): 6
Ic VS. Vce WAVEFORM? (YES=7, NO=0): 7

To title the graph, select option 2 from the PWO's menu:

LABEL THE TITLE
ENTER YOUR GRAPH TITLE:
GRAPH TITLE: D60T753005/DEV8/HARD FWD/
SOME REV/F25K

To plot the selected waveform, choose option 3 from the PWO's menu. Typical waveforms are shown in figures 21 and 22. Refer to characteristic test section for definitions that apply

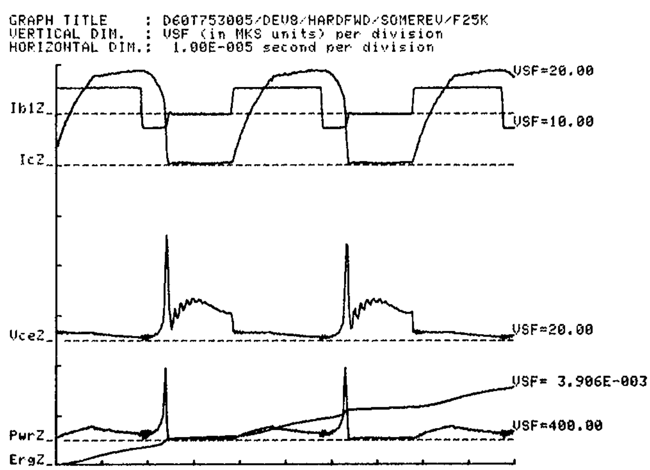

Figure 21.—Typical dynamic switching waveforms.

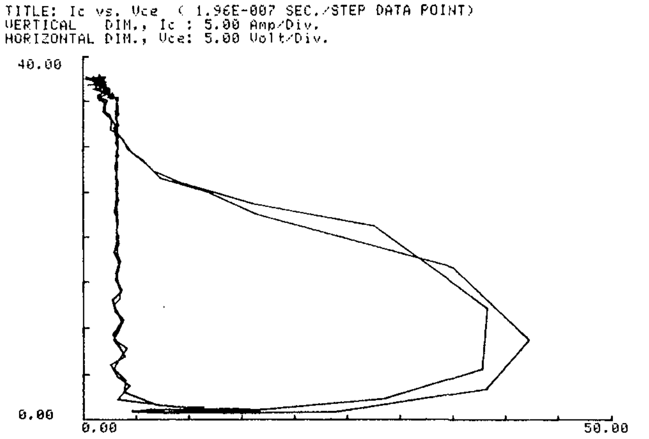

Figure 22. – Instantaneous collector-emitter voltage versus collector current.

to these generated waveforms. To modify the graphical output waveform, select option 4 from the PWO's menu:

WAVEFORM(S) MODIFICATION

Ib1 WAVEFORM: HSCL=1.0E−5, VSCL=10
01. VERTICAL ZERO REFERENCE=3
02. WAVEFORM MULTIPLE NUMBER=0.2

Ib2 WAVEFORM: HSCL=0, VSCL=0
03. VERTICAL ZERO REFERENCE=0
04. WAVEFORM MULTIPLE NUMBER=1

Ic WAVEFORM: HSCL=1.0E−5, VSCL=20
05. VERTICAL ZERO REFERENCE=2
06. WAVEFORM MULTIPLE NUMBER=1

Vce WAVEFORM: HSCL=1.0E−5, VSCL=20
07. VERTICAL ZERO REFERENCE=−1.5
08. WAVEFORM MULTIPLE NUMBER=1

POWER WFM: HSCL=1.0E−5, VSCL=400
09. VERTICAL ZERO REFERENCE=−3.5
10. WAVEFORM MULTIPLE NUMBER=1

ERG WFM: HS=1.0E−5, VS=0.003906
11. VERTICAL ZERO REFERENCE=−4
12. WAVEFORM MULTIPLE NUMBER=0.02

SELECT ITEM # FOR MODIFICATION (0=MENU): 0

This waveform modification option is designed for display purposes. All waveforms can be expanded or reduced in their magnitude, with units being automatically adjusted. Also, their vertical zero references can be shifted up or down along the vertical axis. Each waveform zero level is automatically marked. Since these options are relatively easy to use and self-explanatory, illustrations are not given here.

Limitations/restrictions: There are no guards against waveform clipping in the waveform expansion option. This option must be exercised with care so that no portion of any waveform is clipped off.

Termination routine program module. – This program module is used to confirm the termination of the test. It serves as a reminder to the operator of the power-down sequence procedure so that the test data are not accidentally erased.

Execution: Obtain the main menu and then select option 9 by pressing UDK 9. The program module displays two options and the power-down sequence as shown here:

TERMINATION ROUTINE

1. IF YOU CHANGE YOUR MIND, TYPE IN THE WORD "PLEASE"

2. IF YOU ARE SURE, TYPE IN THE WORD "YES"

ATTENTION:

-DON'T FORGET TO SAVE YOUR TEST DATA BY EXECUTING THE FILE MANAGEMENT PROGRAM MODULE FROM THE MAIN MENU.

-LABEL YOUR TAPE, DISK, AND/OR EXTENDED MEMORY DATA FILES

-POWER-DOWN SEQUENCE:
a) Vcc POWER SUPPLY
b) TEK TM504
c) DAC POWER SUPPLY
d) BASE DRIVE
e) TEK7854 OSCILLOSCOPE
f) TEK4052A DESKTOP COMPUTER
g) TEK4907 FILE MANAGER
h) TEK4643 PRINTER
i) TEK4631 HARD-COPY UNIT

SELECT YOUR OPTION

Options: There are two options in the termination routine program module:

(1) TEST TERMINATION. The operator confirms termination of the test by typing in the word "yes" and hitting the return key.

(2) RETURN TO MAIN MENU. Should the operator change his or her mind or execute the termination routine program module by accident, there is a chance to return to the main menu (without losing the test data) by typing in the word "please."

Bibliography

Cooper, William D.: Solid State Devices: Analysis and Application. Reston Publishing Company Inc., 1974.

Dewan, S.B.; and Straughen, A.: Power Semiconductor Circuits. John Wiley & Sons, Inc., 1975.

Hansen, Irving G.: All Purpose Bidirectional Four-Quadrant Controller. NASA CP-2282, 1982, pp. 189-196.

Hower, P.L.: Optimum Design of Power Transistor Switching. IEEE Trans. Electron Devices, ED-20, April 1973, pp. 462-435.

Hower, P.L.; Brewster, J.B.; and Morozowich, M.: A New Method of Characterizing the Switching Performance of Power Transistors. IEEE Industry Applications Society Conference Record-1978, IEEE, 1978, pp. 1044-1049.

Hower, P.L.: Development and Fabrication of Improved Power Transistor Switches. NASA CR-159524, 1979.

Hower, P.L.: A Comparison of Bipolar and Field Effect Transistors on Power Switches. IEEE Ind. App. Soc Conf. Record 1980, Cincinnati, 1980, pp. 682-688.

Hower, P.L.: High Current, Fast Switching Transistor Development. NASA CR-165372, 1981.

Hower, P.L.: High Voltage Power Transistor Development. NASA CR-165547, 1981.

Shaoan, Chin: MOS-Bipolar Composite Power Switching Devices. Ph.D. Thesis, Virginia Polytechnic Institute & State University, 1985.

Sittig, Roland; Roggwiller, P., eds.: Semiconductor Devices for Power Conditioning. Plenum Press, New York, 1982.

Stobodan, C.; and Middlebrook, R.D.: Advances in Switched-Mode Power Conversion, vol. III, TESLACO Publication, 1983.

Sundberg, Gale R.: New Developments in Power Semiconductors. NASA CP-2282, 1982, pp. 123-142.

Tarneja, K.S.; and Hower, P.L.: A New High Power Switching Transistor. IEEE Ind. App. Soc. Conf. Record 1981, Philadelphia, 1981.

Thomson: CSF Component Corporation, Semiconductor Division: The Power Transistor in Its Environment. Oct. 1978.

Villamil, R.; and Lee, F.C.: Computer Automated System for Measuring Switching Characteristics of Bipolar Power Transistors. Final Report. Virginia Polytechnic Institute and State University, July 1985. (NAG3-99.)

Westinghouse Electric Corporation, Semiconductor Division: Westinghouse Silicon Power Transistor Handbook. First Edition B-9394, 1967.

Wood, Peter: Switching Power Converters. Litton Educational Publishing Inc., 1981.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TP-2554		

4. Title and Subtitle	5. Report Date
Programmable, Automated Transistor Test System	February 1986
	6. Performing Organization Code 506-55-72
7. Author(s) Long V. Truong and Gale R. Sundburg	8. Performing Organization Report No. E-2768
	10. Work Unit No.
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Paper
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Presented in part at Third Symposium on Space Nuclear Power Systems, Albuquerque, New Mexico, January 13-16, 1986.

16. Abstract

A programmable, automated transistor test system was built to supply experimental data on new and advanced power semiconductors. The data will be used for analytical models and by engineers in designing space and aircraft electric power systems. A pulsed power technique was used at low duty cycles in a nondestructive test to examine the dynamic switching characteristic curves of power transistors in the 500- to 1000-V, 10- to 100-A range. Data collection, manipulation, storage, and output are operator interactive but are guided and controlled by the system software.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
High frequency and high power transistors; Advanced power semiconductors; Space and aircraft power applications; Computerized transistor test system	Unclassified - unlimited STAR Category 33

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price*
Unclassified	Unclassified	24	A02

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1986

National Aeronautics and
Space Administration
Code NIT-4

Washington, D.C.
20546-0001

Official Business
Penalty for Private Use, $300

BULK RATE
POSTAGE & FEES PAID
NASA
Permit No. G-27

NASA

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return