Programmable, Automated Transistor Test System

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Cleveland, Ohio
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 Darlington transistors and 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 4052
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 pulsated train of current up to 25 A in magnitude to a single-base transistor or to a Darlington (with two bases). Each pulsated 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
(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)
(5) \( C_s \): snubber capacitor (range, 0.01 to 0.05 \( \mu F \), selectable)

(6) \( R_s \): snubber resistor (range, 20 to 50 \( \Omega \), selectable)

**PATTS Software Structure**

The PATTS software (figs. 4 and 5) was developed under test. 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. 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.](image-url)
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:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_b$</td>
<td>base current waveform</td>
</tr>
<tr>
<td>$I_c$</td>
<td>collector current waveform</td>
</tr>
<tr>
<td>$V_{ce}$</td>
<td>collector-emitter voltage waveform</td>
</tr>
<tr>
<td>$P_{loss}$</td>
<td>power loss waveform, or product of $V_{ce}$ and $I_c$ curves</td>
</tr>
<tr>
<td>$E_{loss}$</td>
<td>energy loss waveform, or integration (area under power loss waveform) of product of $V_{ce}$ and $I_c$ curves</td>
</tr>
<tr>
<td>$I_c$ vs $V_{ce}$</td>
<td>collector current versus collector-emitter voltage waveform</td>
</tr>
<tr>
<td>$t_d$</td>
<td>delay time, or time from application of input base current until output collector current has reached 10 percent of its final value</td>
</tr>
<tr>
<td>$t_r$</td>
<td>rise time, or time required for output collector current to go from 10 to 90 percent of its saturation value</td>
</tr>
<tr>
<td>$t_s$</td>
<td>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</td>
</tr>
</tbody>
</table>
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:

- $I_b$ 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.]

<table>
<thead>
<tr>
<th>CASE</th>
<th>BASE-DRIVE INFORMATION</th>
<th>TESTING FREQUENCY</th>
<th>FORWARD (I_b) DRIVE</th>
<th>REVERSE (I_b) DRIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CASE 1</strong></td>
<td></td>
<td>25 kHz</td>
<td>3 STEPS</td>
<td>0</td>
</tr>
<tr>
<td><strong>CASE 2</strong></td>
<td></td>
<td>25 kHz</td>
<td>3 STEPS</td>
<td>1 STEP</td>
</tr>
<tr>
<td><strong>CASE 3</strong></td>
<td></td>
<td>25 kHz</td>
<td>10 STEPS</td>
<td>1 STEP</td>
</tr>
</tbody>
</table>

### 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/ RESISTOR RATING:** FROM 1 to 10 kW (DEPENDING ON DUTY CYCLE)
- **L/INDUCTOR RATING:** 23 \(\mu\)H, 50 A, \(r=0.00115\)
- **C/ CAPACITOR RATING:** 0.047 \(\mu\)F, 800 V
- **Rs RESISTOR RATING:** 25 \(\Omega\), 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

---

**GRAPH TITLE:** D60T753005/DEV1/LOWFWD/HDREV/F25K

**VERTICAL DIM.:** 1.00E+005 second per division

**HORIZONTAL DIM.:** 1.00E+005 second per division

**USF 13.23**

**USF 3.90E-002**

**USF 20.00**

**USF 4.00**

**USF 20.00**

**USF 3.90E-002**

**USF 400.00**

**USF 400.00**

**USF 400.00**

**USF 400.00**

**USF 400.00**

**USF 400.00**

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**USF 400.00**

**USF 400.00**

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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).
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 Vce 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 Vce 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 Vce (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

\[ V_{CEO} \text{ Test} \]

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 breakdown 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.

\[ I_{CEO} \text{ Test} \]

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

\[ BV_{CBO} \text{ and } I_{CBO} \text{ Tests} \]

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).

\[ BV_{EBO} \text{ and } I_{EBO} \text{ Tests} \]

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:

   **TRANSPORTER TEST EXECUTIVE TAPE**

   **FILE #** | **CONTENTS**
   ---------------
   1             | SYSCLOCK/TAPE LISTING/AUTO LOAD
   2             | NPN TRANSPORTER TEST UDK'S AND MENU
   3             | NPN USER-DEFINEB KEYS (UDK'S)
   4             | NPN TRANSPORTER TEST MENU
   5             | HELP/INTRODUCTION
   6             | BASE-DRIVE REMOTE OPERATION
   7             | INITIALIZATION
   8             | CONSTANT INPUT:
   9             | HEADER INFORMATION
   10            | DEVICE RATING
   11            | TEST CIRCUIT PARAMETERS
   12            | TRANSPORTER TEST PROCESSING:
   13            | DYNAMIC WAVEFORMS
   14            | DC MEASUREMENTS
   15            | DATA FILE MANAGEMENT:
   16            | CREATE-SAVE-LOAD-MODIFY
   17            | (DISK, TAPE, AND EXTENDED MEMORY)
   18            | TEST OUTPUT PACKAGE:
   19            | NUMERICAL DATA LISTING
   20            | CIRCUIT DIAGRAM
   21            | PLOTTING WAVEFORMS
   22            | 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
PNGAIN11
NPNPRINT41
NPNTAPEDIR
NPNMENU1
NPNTTEST6
NPNFILE7
NPNCHG
NPnnINIT4

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
NPnnINIT4 initialization
NPNCONST5 constant data input
NPnnTEST6 transistor test processing
NPNFILE7 file management
NPNOUTPUT8 output package
NPnnTERM9 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. (PRESS HOME PAGE KEY TO SEE NEXT PAGE)

**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
2.0 SET FORWARD BASE(1) CURRENT AT N(00-31)
3.0 SET REVERSE BASE(1) CURRENT AT M(00-32)
4.0 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 × 4 steps)
Option 3.4 set -2 A (-0.5 A/step × 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
06. LOAD DIODE D1: PTC 900
07. SNUBBER DIODE D2: PTC 900
08. LOAD RESISTOR R#: FROM 1 to 10 kW (DEPENDING ON DUTY CYCLE)
09. LOAD INDUCTOR L#: 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
05. BASE(2) CURRENT WAVEFORM PROCESSING
06. COLLECTOR CURRENT WAVEFORM PROCESSING
07. COLLECTOR-EMITTER VOLTAGE PROCESSING
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 $V_{BE0}$, 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 $\mu$s/cycle (20 kHz)
  • From FG 501A, set envelope pulses at approx 8 ms/cycle ($50 \times 16 \times 10 \mu$s) 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 TRANSFERRED ...

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.

(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 I_b AND I_c WAVEFORMS BETWEEN 2 CURSORS:
• USE (CRS1) and (CRS2) KEYS FROM TEK7854 OSCILLOSCOPE

Figure 10. — Base (1) current waveform.

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:

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
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 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" I_{b1} 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" I_{b1} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{b1} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{b1} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{b1} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{b1} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{b2} WAVEFORM AGAIN? (Y/N): N
DO YOU WANT TO "SMOOTH" I_{c} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" I_{c} WAVEFORM AGAIN? (Y/N): Y
DO YOU WANT TO "SMOOTH" V_{ce} WAVEFORM AGAIN? (Y/N): Y

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

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

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:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HELP</td>
</tr>
<tr>
<td>2</td>
<td>MODIFY</td>
</tr>
<tr>
<td>3</td>
<td>SAVE</td>
</tr>
<tr>
<td>4</td>
<td>LOAD</td>
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<tr>
<td>5</td>
<td>SAVE</td>
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<tr>
<td>6</td>
<td>LOAD</td>
</tr>
<tr>
<td>7</td>
<td>SAVE</td>
</tr>
<tr>
<td>8</td>
<td>LOAD</td>
</tr>
<tr>
<td>9</td>
<td>MAIN MENU</td>
</tr>
</tbody>
</table>

**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/NN1/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:
---------------------------------------
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

-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)

HEADER INFORMATION
MANUFACTURER: WESTINGHOUSE/D60T75905
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
Rf RESISTOR RATING: FROM 1 to 10 kW (DEPENDING ON
DUTY CYCLE)
L1 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
Vce 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
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 key 4 and then the return key. A submenu for the plotting arrangement of these waveforms 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.
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 accidently 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.”

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


## 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.