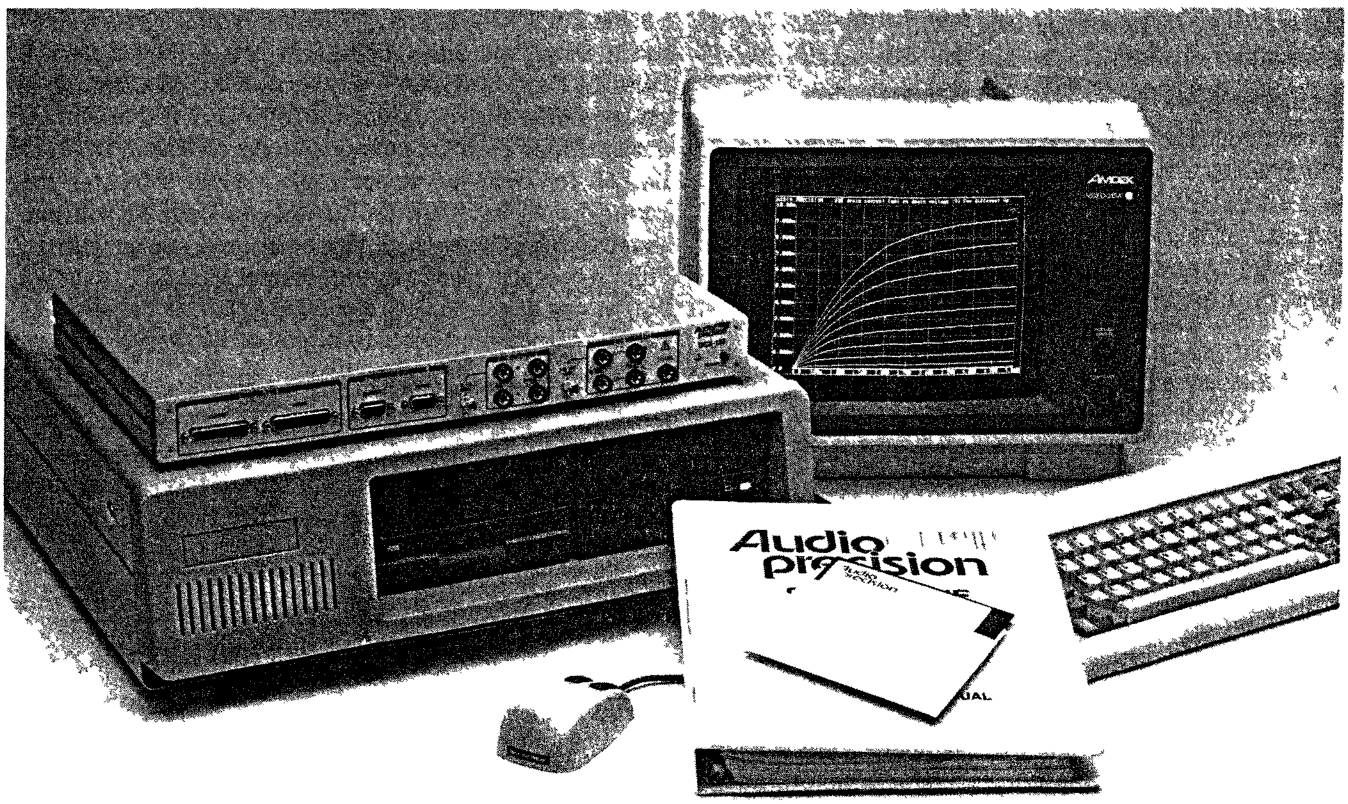
Audio precision

Application note

2 in a series

SYS-127 APPLICATIONS

TABLE OF CONTENTS



SYS-127 APPLICATIONS

This applications note deals with dc, resistance, and digital tests and control which can be done automatically (and graphically) with the SYS-127. It is not intended to be a comprehensive treatment of all the types of tests which could be done with this instrument. Instead, the purpose of this note is to stimulate the reader's ideas in his or her own applications area by discussing a number of specific examples.

The SYS-127 consists of the Audio Precision DCX-127 multi-function dc and digital input-output instrument plus the interface card, cable, and comprehensive software package necessary to operate it from an IBM PC, XT, AT, or 386-compatible computer. The software requires 640k memory and a CGA, EGA, VGA, or Hercules monochrome graphics display system. It may be used with one or more diskette and/or hard disk drives. A math co-processor is highly recommended for fastest operating speeds, but is not required.

The DCX-127 includes a 4 1/2 digit autoranging dc voltmeter-ohmmeter, two independently controllable precision voltage sources variable across a ±10.5 Volt dc range with 20 microvolt resolution, 21-bit plus sign parallel digital input and output words, and 24 bits of control logic outputs plus several other features. Digital I/O and control logic outputs are LSTTL-compatible. For specifications, see the last two pages of this note.

A comprehensive software package named S1.EXE (S1H.EXE for the Hercules version) is included as part of the SYS-127. This software (referred to as S1 in the remainder of this note) is menu-panel-graph oriented. No knowledge of any computer programming language is required, nor is prior experience in programming.

The software permits real-time measurements to be viewed in either analog bargraph or numeric display forms. It also permits real-time graphs of one or two simultaneous measurements to be plotted against a swept dc or digital stimulus or against time in chart recorder fashion. Any test setup can be saved to disk for later use. Data can be saved to disk and later retrieved for display in color graphic, monochrome graphic, or tabular formats. Multiple tests can be linked together into complete test procedures by a keystroke "learn mode" which requires no programming experience. Limits can be created and attached to any test for go/no-go results comparison. Graphic or hard copy printout can be made to economical dot-matrix printers at the touch of a key, or automatically during a procedure. The DCX-127 additionally has features which permit replacing the computer keyboard with a simple keypad or a few switches in those applications where a full computer keyboard may be intimidating to unskilled operators.

This applications note will discuss many of the capabilities of the SYS-127 and will show examples of each class of applications. Many other applications will be similar to those discussed here, and the test setups and procedures can be patterned on those shown in this note.

Overview of S1.EXE Software

The software furnished with an SYS-127 was developed to control Audio Precision's comprehensive System One audio test system, of which the DCX-127 is one optional component. There are therefore many features of the software which are not relevant to DCX-127 applications. They will not impede DCX-127 operation, however.

S1.EXE software control capability includes a single-line menu at the bottom of the screen plus eight panels. Only three of those panels are used in DCX-127 operation. A companion diskette to this applications note contains a number of tests, procedures, and batch files. The batch files DCX.BAT or DCXH.BAT may be used for maximum convenience in loading and using the SYS-127. If the software is started from the DOS prompt with the command DCX (or DCXH, for Hercules monochrome version software), the corresponding batch file on the diskette loads S1 software and runs a procedure which selects the three relevant panels. This process also loads a test file named STD.TST (standard test) which has pre-selected the DCX-127 as the stimulus source and measurement to be displayed for graphic testing.

The menu structure has two levels for most activities. The top level (CMD, for COMMAND) is reached from any screen via the <Esc> key (see Figure 1). Selecting most items in the CMD menu causes a second-level menu to be displayed for that particular action. See Figure 2 for an il-

```
CMD: RUN PANEL LOAD SAVE APPEND EDIT HELP XDOS DOS NAMES IF UTIL QUIT COMPUTE
Run procedure, test, or graphs                AUDIO PRECISION SYSTEM ONE, v1.60C
```

Figure 1 Command Menu

```
LOAD: TEST LIMIT SWEEP COMMENT PROCEDURE MACRO DATA EQ IMAGE OVERLAY
Load entire test from .TST file          AUDIO PRECISION SYSTEM ONE, v1.60C
```

Figure 2 Load Menu

lustration of the LOAD menu, obtained by selecting LOAD from the CMD menu. Some CMD menu selections such as PANEL are single level. The menu is used primarily for computer-intensive actions such as loading a test setup from disk into memory, saving test setups or data to disk, linking together multiple tests into procedures, attaching limit files to tests, making temporary exits to the computer operating system to run other programs during a procedure, etc.

Selection of menu items is done in either of two fashions. ~ne is by using the space bar to move the inverse-video cur-sor onto the desired item, then pressing the <Enter> key. The second method is simply to press the key corresponding to the first character of the menu item--<L> for Load, <T> for Test, etc.

While the menu is used for computer-oriented actions, PANEL mode is used to actually control the DCX-127 instrument and to display "spot" measurements. If the software was loaded with the DCX or DCXH batch file process described above, or if the procedure DCX.PRO was run after software startup, the panels displayed when PANEL is selected will be as shown in Figure 3. If other panels have accidentally or deliberately been displayed, load and run the procedure DCX.PRO to restore these three panels to the screen.

```
-DCX-----------------LOCAL-
 MM                      Vdc
  OFFSET-f 0.0
  SCALE-f  1.0
  RANGE                 AUTO
  RATE     6/sec

DC OUT 1   0.0          Vdc
DC OUT 2   0.0          Vdc

DIGITAL IN              DEC
  SCALE-g  1.000        2sC
  RATE     32/sec
DIGITALOUT 0            DEC
  SCALE-h  1.000        2sC

PORT OUT A 0            DEC
         B 0            DEC
         C 0            DEC

GATE DELAY 50.00       msec
```

```
-SWEEP TEST DEFINITIONS-
  (press F9 to sweep)
DATA-1     DCX      DMM
GRAPH TOP  10.0000  Vdc
  BOTTOM   -10.000  Vdc
  # DIVS   10       LIN

DATA-2     DCX     NONE
GRAPH TOP           OFF
  BOTTOM            OFF
  # DIVS   0        LOG

SOURCE-1   DCX   DCOUT1
  START    0.0      Vdc
  STOP     1.00000  Vdc
  # DIVS   0        LIN

# STEPS    10
  TABLE    OFF

DISPLAY    MONO-GRAPH
```

```
-SWEEP SETTLING-
   TOLERANCE  RESOLUTION
AMPL 1.000 %  100.0   nV
LVL  1.000 %  25.00   uV
THD  3.000 %  0.00007 %
IMD  3.000 %  0.00003 %
FREQ 0.500 %  0.00020 Hz
W+F  5.000 %  0.00020 %
DCV  0.200 %  500.0   uV
OHMS 0.500 %  100.0   mΩ
D-IN 0.000 %  1.000   LSB
PHASE         0.50    DEG

SETTLING    EXPONENTIAL
  DATA      3    SAMPLES
  DELAY     30.00   msec
  TIMEOUT   4.00     sec

EXT SOURCE 3     SAMPLES
  MIN LVL   10.00   mV
```

```
Vdc f(V) OHMS f(Ω) OFF              To change setting, use SPACE bar.
DMM Units                           To select another field, use arrow keys.
```

Figure 3 DCX-127, Sweep Test Definitions, and Sweep Settling Panels

The DCX-127 control and display panel is displayed at the left of the screen. The SWEEP TEST DEFINITIONS panel is displayed at the screen center, and the SWEEP SETTLING panel at screen right.

For simple real-time setting of the DCX-127 dc or digital stimulus and simple observation of the dc, resistance, or digital measurements, only the DCX-127 panel is necessary. The SWEEP TEST DEFINITIONS panel permits setup of sweeps of dc or digital stimulus and selection of which measurements will display as lines on a graph when the F9 function key is pressed to start a test. This panel also permits flexible selection of units and graphic coordinates. Real-time bargraphs (see Figure 5) may be displayed by pressing the F2 function key. The SWEEP TEST DEFINITIONS panel also controls the bargraph calibrations.

The SWEEP SETTLING panel controls how S1 software determines whether measurement results are sufficiently steady-state to retain and plot a measurement point. The settling concept involves continually examining the stream of measurements furnished by the DCX-127 hardware. Only when the several most-recent measurements agree with one another within a tolerance "window" specified by the user on the SWEEP SETTLING panel will the software retain and plot the most recent point and move on to the next measurement. Settling may be turned off when it is desired to plot every measurement, regardless of data variations.

Additional capabilities and features of S1 software will be discussed as they apply to specific applications described below. A comprehensive treatment of S1 software may be found in the User's Manual, furnished with the SYS-127 system.

Single Point DC and Resistance Measurements

Dc voltage up to 500 Volts can be measured with the DCX-127. Resolution of the voltmeter varies from 10 microvolts on the 200 mV range to 0.1 Volt on the 500 Volt range. Resistances up to 2.5 Megohms can also be measured, with resolution varying from 10 milliohms (200 Ohm range) to 200 Ohms (2 Megohm range). Four-wire (Kelvin) connections may be made to the unknown device to reduce the influence of lead resistance when measuring low values of resistance.

Dc or resistance measurement mode is selected in the top line of the DCX-127 panel; see Figure 3. Dc voltage may be directly displayed in Volts and millivolts, or f(V) may be selected. With f(V) as units, the actual dc measurement will be scaled and offset by the "scale" and "offset" values entered on the DCX-127 panel before display. Similarly, resistance may be displayed as Ohms or may be scaled and offset with f(Ω). Offset and scaling are commonly required when the device being measured is a transducer such as a temperature or pressure sensor. Appropriate selection of offset and scaling factors can then often produce a display directly in engineering units such as degrees or pounds per square inch.

If it is desired to do more than simply observe readings on the DCX-127 panel, the SWEEP TEST DEFINITIONS panel and certain function keys come into play. For single-point measurements of dc or resistance which can be compared to limits, saved to disk, or printed, select DCX NONE as SOURCE-1 at the bottom of the panel. This mode automatically selects tabular display even if MONO-GRAPH or COLOR-GRAPH is selected, and creates a single-point measurement. At DATA-1, select DCX, then the desired dc or resistance mode. To obtain resistance modes on the SWEEP TEST DEFINITIONS panel, OHMS or f(Ω) must have been selected on the DCX-127 panel. Similarly, Vdc or f(V) must be selected on the DCX-127 panel if DATA-1 is to be selected as dc voltage. Example single-point test files for measuring voltage and resistance are stored on the diskette under the names SING-VDC.TST and SING-OHM.TST.

When the selections are made, press F9 for a measurement. The name of the test, date and time, and the measurement will be displayed on the screen (see Figure 4). To save the setup or data, <Esc> to the menu, use the Save Test command, and supply an appropriate file name to avoid over-writing the STD.TST file automatically loaded by the DCX.PRO procedure. If we were setting up a battery cell test for a model 19 cell, for example, we might select a name such as CELL19. S1 software will automatically supply the .TST file extension when <Enter> is pressed. If you were now to re-display the test result by pressing the F7 function key, the display would be identical to Figure 4 except for the new test name which you supplied. CELL19.TST is stored on the diskette as an example.

```
STD  28 JUL 88  12:46:28
NONE(OFF)      DMM(Vdc)
    OFF   1.31770  Vdc
```

Figure 4 Screen Display of Single-Point Measurement

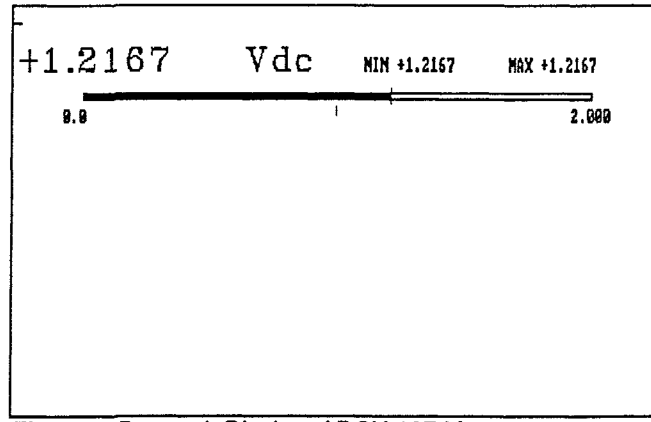


Figure 5 Bargraph Display of DCX-127 Measurements

The measurement may also be displayed on the computer screen in analog bargraph fashion by pressing the F2 function key. The end points of the bargraph and the logarithmic or linear relationship of the bargraph to the data are selected at the DATA-1 area near the top of the SWEEP TEST DEFINITIONS panel. See Figure 5 for an example bargraph display. The rate of updating of the bargraph is controlled by the 6/second vs 25/second rate selection for the DCX-127 panel numeric display, selected on the DCX-127 panel. The faster rate provides more rapid feedback for making adjustments, but the slower rate provides better resolution for critical tests.

Limits

In automated testing, it is often desired to have the computer compare a measurement to allowable performance limits and make a decision as to whether to accept the result. Limit files are easily created in S1 software in the Edit Data mode. The following discussion is an overview of limits file creation and use; see the User's Manual for more details.

Load the test file to which limits will be attached and press <Esc> Edit Data. Figure 6 shows a typical result, with the column heads plus data if the F9 key has been pressed. Move the cursor into the second line, below the column heads. Use the delete key or block delete capability (F6 <Ctrl><PgDn> F6) to erase any data there. Type in a zero

```
----|----1----|‖---2----|----3----|----4----|----5----|----6----|--
          OFF                 Vdc                  OFF
          1000,         1.31769991
```

Figure 6 Example of Edit Data Display After Single-Point Measurement

and comma for the SOURCE-1 column (under the heading OFF), and the allowable upper limit for the measurement in the second column; see Figure 7. <Esc> to the menu, select Save Limit, and supply a name which will identify both the name of the test and the fact that this is an upper limit file. For a battery cell test, an example name might be `ELL19UP <Enter>. S1 software will automatically supply the .LIM file extension and save the result as CELL19UP.LIM. To create the lower limit, press Edit Data and replace the upper limit value in the second column, second row with the lower limit value (see Figure 8). <Esc> and Save Limit as, for example, CELL19LO.LIM. CELL19UP.LIM and CELL19LO.LIM are stored on the diskette as examples.

To attach these two limit files to the test file, use <Esc> Load Test and the cursor keys to select and re-load the CELL19.TST test. Then use the Names Upper command, place the cursor on CELL19UP.LIM, and press <Enter>. Use Names Lower, select CELL19LO.LIM, and press <Enter> to specify the lower limit. To verify that the files are properly attached, select Names; you should see a display similar to Figure 9. This shows the test name and limit file names. The test file must now be re-saved with these limit file names attached, in place of the original version of CELL19.TST. Press <Esc> Save Test, <Enter>, and press *Y* to approve of the software over-writing the original test version which did not have limit files specified.

```
----|----1----|‖---2----|----3----|----4----|----5----|----6----|--
          OFF                 Vdc                  OFF
          0,            1.35
```

Figure 7 Example Upper Limit File

```
----|----1----|‖---2----|----3----|----4----|----5----|----6----|--
          OFF                 Vdc                  OFF
          0,            1.0
```

Figure 8 Example Lower Limit File

```
Title of Graph                    = AUDIO PRECISION

Procedure Name                    =
File in Memory                    = CELL19.TST
Comment Name                      =
Data Name                         =
Macro Name                        =
Upper Compare File                = CELL19UP.LIM
Lower Compare File                = CELL19LO.LIM
Sweep Source File                 =
Gen1#1 Equalization File          =
Compute Delta File                =
Error Reporting File              =

Maximum Data Points               = 986    (     1 used)
Internal EQ, Limit, Sweep Points  = 200
Maximum Edit-Data Size            = 59217  (   101 used +     0 in copy buffer)
Maximum Edit-Procedure Size       = 32470  (     0 used +     0 in copy buffer)
Maximum Edit-Comment Size         = 32470  (     0 used +     0 in copy buffer)
Maximum Edit-Macro Size           = 7213   (     0 used +     0 in copy buffer)
Bytes Reserved for DOS            = 32769

NAMES: UPPER LOWER SWEEP GEN1#1-EQ ERROR-FILE OFF TITLE RENAME-TEST CLEAR DELTA
Select file for upper compare limit          AUDIO PRECISION SYSTEM ONE, v1.60C
```

Figure 9 Names Display

When a tabular display test with limits attached is run (F9 key), the display will show any outside-limits result. Figures 10 and 11 are examples of both passing and failing tests. The measurement and the limit value exceeded are both displayed in the case of failure. Note that this is the simplest of several pass/fail techniques in the software package. S1.EXE software can also automatically write passing messages or failure data into an error summary file, and one error summary file can be used for any number of tests in a complete procedure. S1.EXE software can also take conditional action in a procedure upon failure or success. Coupled with screen and logic output capabilities, an automatic procedure can thus signal the pass/fail decision to an operator via PC screen or separate annunciator or can even control a device handler. See the User's Manual for more details.

```
CELL19  20 JUL 88  12:46:28
NONE(OFF)      DMM(Vdc)
    OFF   1.30570  Vdc
```

Figure 10 Example Screen Display, Passing

```
CELL19  20 JUL 88  12:46:28
NONE(OFF)      DMM(Vdc)
    OFF   .997077  Vdc below 1.00000
```

Figure 11 Example Screen Display, Failing

Simple, single-point measurements of voltage or resistance with limits comparisons are perhaps the most common application of the SYS-127. Checking dc power supply voltages, amplifier offset voltages, battery voltages, resistance values, and dozens of other common applications are typical of this operation. Multiple tests on the same device can be linked together into an automatic procedure. Prompting messages to the operator may be interspersed as desired. See the Procedures chapter of the User's Manual for more information on creating procedures.

DC or Resistance Measurements vs Time

Sometimes it is necessary to measure a dc voltage versus time. One example is testing the charge lifetime of a cell or battery while connected to a specific load resistance. Another example is stability testing of power supplies while load, input voltage, or environmental conditions such as temperature are varied.

For measurements versus time, change the SOURCE-1 selections near the bottom of the SWEEP TEST DEFINITIONS panel to EXTERN TIME. Fields will then appear for the START and STOP values. Units of seconds, minutes, or hours may be selected. LIN would normally be selected for the horizontal axis time calibration, but LOG could be selected to space measurement samples logarithmically in time. Figure 12 shows an example panel for testing NiCd rechargeable batteries, with 0 and 180 minutes selected as the START and STOP times. Enter a value for # STEPS which will produce data samples of the desired frequency during the test. For the example shown, the 180 minute duration and 720 STEPS will cause a reading to be taken every 15 seconds. At DATA-1, select GRAPH TOP and BOTTOM values to properly display the expected voltage range over the life of the test. Press F9 to start the test. Figure 13 is an example of a NiCd battery discharge. This test is stored as DCVSTIME.TST on the companion diskette.

Limit files of any desired shape may be created for tests with a "swept" SOURCE-1 value in a manner similar to single point limits described above. For the NiCd battery test, the Edit Data command could be used to enter values such as shown in Figure 14. Note that SOURCE-1 values are now required in the first column, rather than the 0 entered for single-point measurements. The limit file may be graphically displayed by pressing <Esc> F7; see Figure 15 for an example. If this file were saved as a lower limit file and attached via the Names Lower command, every data point taken during a test will be compared to a limit value interpolated from the nearest horizontal points in the limit file. If desired, an attached limit file may be graphed before or after a test is run by pressing <Alt>F7. Figure 16

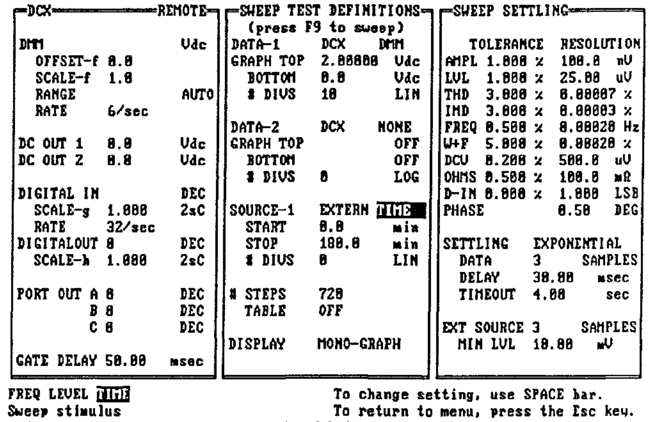


Figure 12 Setup Panels for Voltage vs Time Measurement

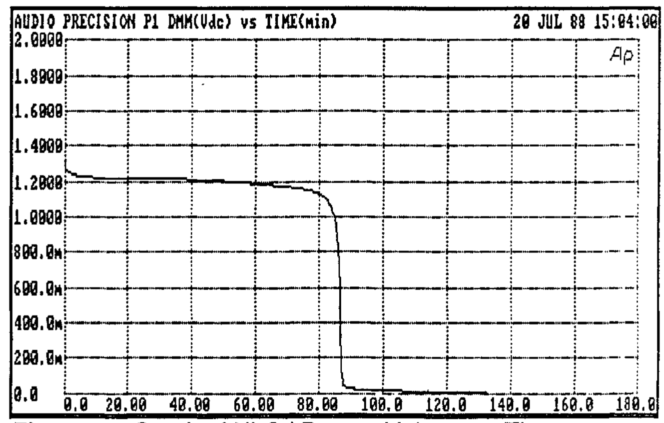


Figure 13 Graph of Ni-Cd Battery Voltage vs Time

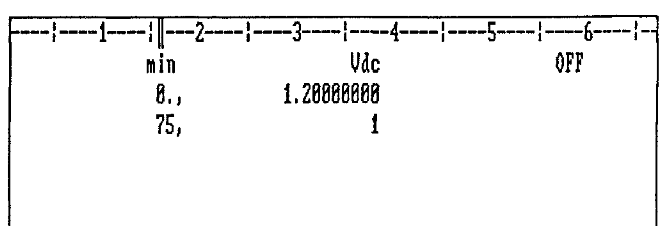


Figure 14 Lower Limit File for Ni-Cd Battery Test

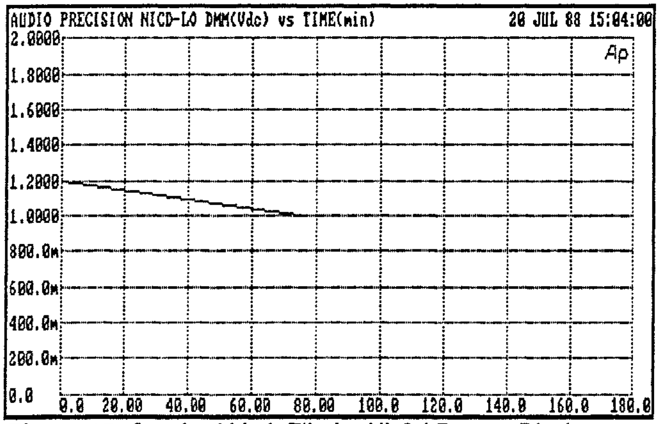


Figure 15 *Graph of Limit File for Ni-Cd Battery Discharge Test*

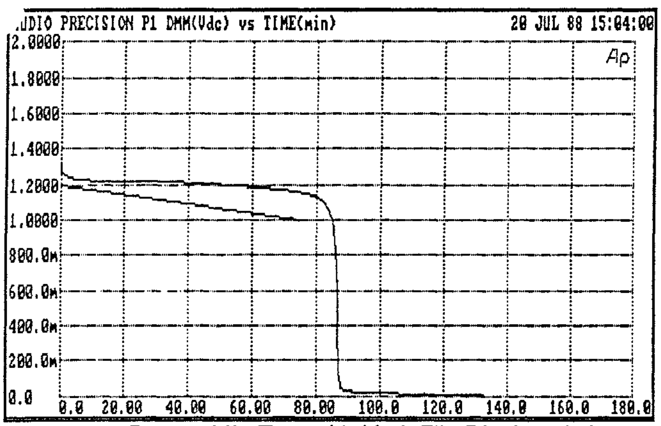


Figure 16 *Battery Life Test with Limit File Displayed via <Alt>F7 Keystroke*

is an example of the NiCd battery life test from Figure 13 with the limit file of Figure 14 attached. This example limit file is storedd as DCTIMELO.LIM.

Stimulus-Response DC Measurements

In addition to measuring dc at a single instant or versus time, dc voltage (or resistance) may be measured as a function of a stepped dc voltage stimulus. Examples include testing the dc transfer characteristics of FETs, linear ic's, bipolar transistors, opto-isolators, and varistors or other non-linear resistors.

Nested Sweeps

The two dc outputs of the DCX-127 can be particularly valuable in such testing, with one driving one junction or port while a second controls another junction or serves as a power supply. S1 software permits a feature known as nested sweeps, which can create an entire family of curves in one test. Stimulus parameters may be selected both at SOURCE-1 and at SOURCE-2. SOURCE-2 is an alternate selection to DATA-2, near the center of the SWEEP TEST DEFINITIONS panel. When SOURCE-2 is selected, the GRAPH BOTTOM value must be interpreted as "SOURCE-2 START" and GRAPH TOP must be interpreted as "SOURCE-2 STOP". The # STEPS value determines the number of steps which SOURCE-2 will take between those end values. The span between SOURCE-2 GRAPH BOTTOM and TOP will be divided into equal increments for the steps if LIN is selected, and into equal percentage steps if LOG is selected (and if both values are positive). When F9 is pressed, SOURCE-2 is set to the starting (GRAPH BOTTOM) value and SOURCE-1 is stepped through its specified range. SOURCE-2 is then incremented one step towards its GRAPH TOP value and the SOURCE-1 sweep is repeated. This process continues through the final SOURCE-1 sweep at the SOURCE-2 ending (GRAPH TOP) value. The result is a family of curves.

Figure 17 is the block diagram of the connections between the DCX-127 and a field-effect transistor (FET). DC output #1 is used to control the gate voltage. DC output # 2 is used as the drain supply. A 10 Ohm current-sensing resistor is used between DC output #2 and the drain, with the dc voltmeter measuring current by measuring the voltage drop across the resistor. Figure 18 shows the setup panels, where

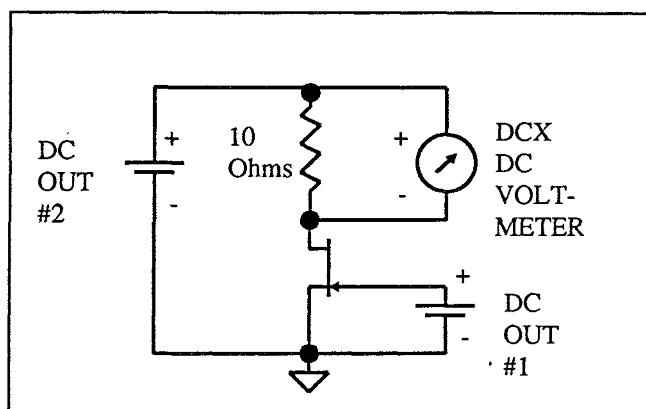
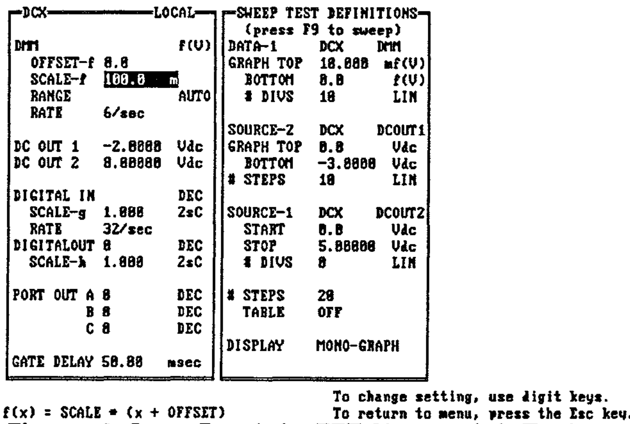


Figure 17 *Block Diagram, FET Characteristic Testing*



```
DCX                  LOCAL      SWEEP TEST DEFINITIONS
                                   (press F9 to sweep)
DMM                      f(V)   DATA-1      DCX     DMM
  OFFSET-f  0.0                 GRAPH TOP   10.000  mf(V)
  SCALE-f   100.0    m            BOTTOM    0.0      f(V)
  RANGE                  AUTO     # DIVS    10       LIN
  RATE      6/sec
                                SOURCE-2    DCX     DCOUT1
DC OUT 1    -2.0000   Vdc       GRAPH TOP   0.0      Vdc
DC OUT 2    0.00000   Vdc         BOTTOM    -3.0000  Vdc
                                # STEPS     10       LIN
DIGITAL IN            DEC
  SCALE-g   1.000     2sC       SOURCE-1    DCX     DCOUT2
  RATE      32/sec                START     0.0      Vdc
DIGITALOUT 0          DEC         STOP      5.00000  Vdc
  SCALE-h   1.000     2sC         # DIVS    0        LIN

PORT OUT A 0          DEC       # STEPS     20
         B 0          DEC         TABLE     OFF
         C 0          DEC
                                DISPLAY     MONO-GRAPH
GATE DELAY 50.00      msec

                                 To change setting, use digit keys.
f(x) = SCALE * (x + OFFSET)      To return to menu, press the Esc key.
```

Figure 18 Setup Panels for FET Characteristic Testing

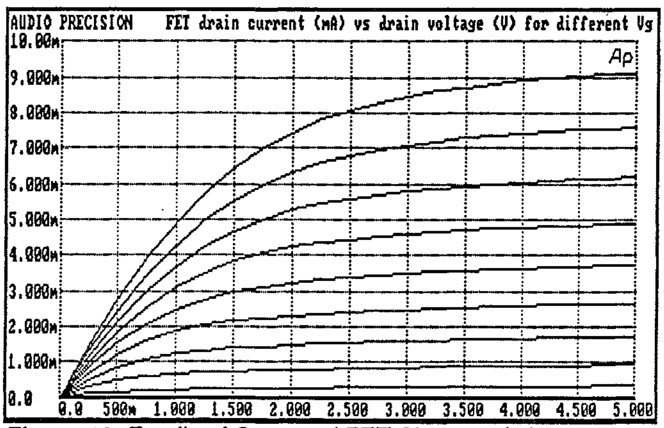


Figure 19 Family of Curves of FET Characteristics

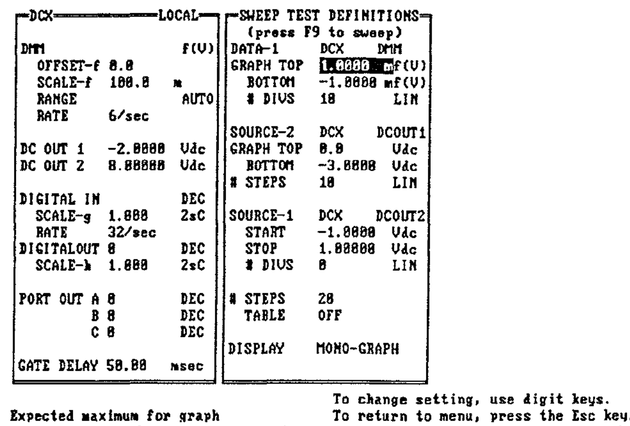
the gate voltage is swept between 0 and -3 as SOURCE-2 while the source supply is stepped from 0 to 5V by SOURCE-1. This example test is stored on the companion diskette as FET-CHAR.TST. Figure 19 shows the result. This data could be saved to disk for a number of different FETs, with the Append Test command or graphic overlay capability (<Alt>F8/F8) then used to compare devices for matching.

When it is desired to know exactly which SOURCE-2 values correspond to the various curves, change to DISPLAY TABLE and press F7. Use F10 (pause key) to suspend the data scrolling as desired. Figure 20 shows a section of the resulting display, at the transition between two SOURCE-2 values.

FET-CHAR 09 JUN 88 06:26:55

DCOUT2(Vdc)	DMM(Vdc)	DCOUT1(Vdc)
4.25000 Vdc	380.000 uVdc	-2.7000 Vdc
4.50000 Vdc	400.000 uVdc	-2.7000 Vdc
4.75000 Vdc	420.000 uVdc	-2.7000 Vdc
5.00000 Vdc	430.000 uVdc	-2.7000 Vdc
——— Vdc	——— Vdc	——— Vdc
0.0 Vdc	-20.000 uVdc	-2.4000 Vdc
250.000 mVdc	1.25000 mVdc	-2.4000 Vdc
500.000 mVdc	1.73000 mVdc	-2.4000 Vdc
750.000 mVdc	2.02000 mVdc	-2.4000 Vdc

Figure 20 Tabular Display of Data at a Transition Point in a Nested Sweep Series



```
DCX                  LOCAL      SWEEP TEST DEFINITIONS
                                   (press F9 to sweep)
DMM                      f(V)   DATA-1      DCX     DMM
  OFFSET-f  0.0                 GRAPH TOP   1.0000  mf(V)
  SCALE-f   100.0    m            BOTTOM    -1.0000 mf(V)
  RANGE                  AUTO     # DIVS    10       LIN
  RATE      6/sec
                                SOURCE-2    DCX     DCOUT1
DC OUT 1    -2.0000   Vdc       GRAPH TOP   0.0      Vdc
DC OUT 2    0.00000   Vdc         BOTTOM    -3.0000  Vdc
                                # STEPS     10       LIN
DIGITAL IN            DEC
  SCALE-g   1.000     2sC       SOURCE-1    DCX     DCOUT2
  RATE      32/sec                START     -1.0000  Vdc
DIGITALOUT 0          DEC         STOP      1.00000  Vdc
  SCALE-h   1.000     2sC         # DIVS    0        LIN

PORT OUT A 0          DEC       # STEPS     20
         B 0          DEC         TABLE     OFF
         C 0          DEC
                                DISPLAY     MONO-GRAPH
GATE DELAY 50.00      msec

                                 To change setting, use digit keys.
Expected maximum for graph       To return to menu, press the Esc key.
```

Figure 21 Setup Panels for Measuring FET Characteristics Around Zero Volts

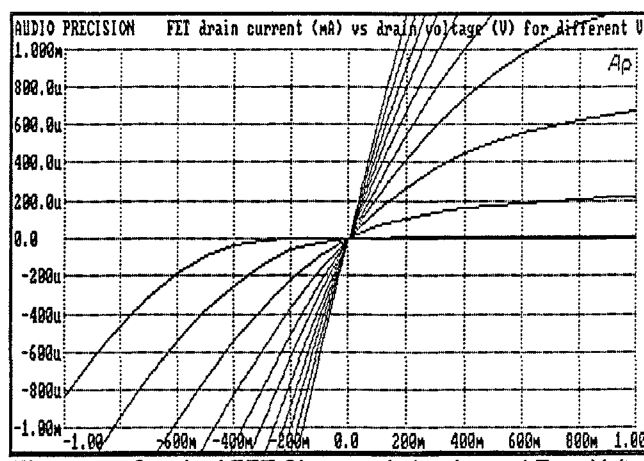


Figure 22 Graph of FET Characteristics Around Zero Volts

To examine the characteristics around zero volts, Figure 21 shows a panel setup and Figure 22 the resulting graph. The display may be expanded for greater detail after taking data. This example is saved as FET-ZERO.TST on the diskette.

Measuring Resistance While Varying Voltage

Many devices, including FETs and LDRs (light-dependent resistors) exhibit a variable resistance as a function of an applied control voltage or current. The DCX-127 ohmmeter can be used to measure the resistance while the voltage of one of the DC outputs is varied.

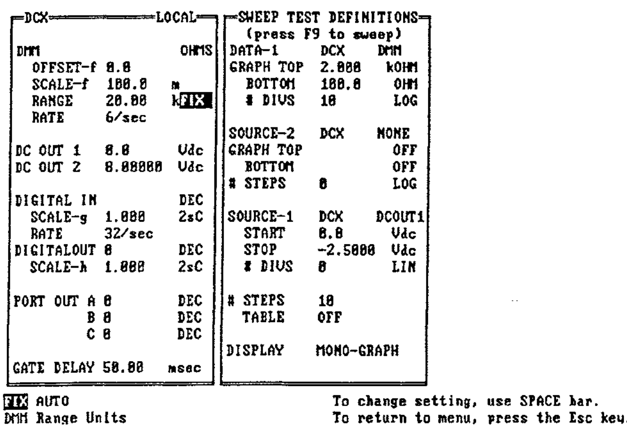


Figure 23 Setup Panels for Measuring FET Drain-Source Resistance as a Function of Gate Voltage

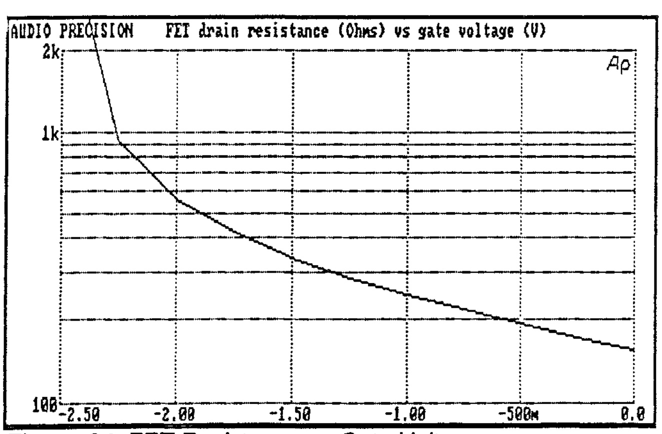


Figure 24 FET Resistance vs Gate Voltage

Figure 23 shows the setup panels, saved as LDR-RES.TST on the diskette. Figure 24 a representative graph of FET drain-source resistance as the gate voltage is varied. To prevent the ohmmeter from autoranging and thereby changing the voltage used for resistance measurements, it should be fixed on an appropriate range. In the example shown the meter was fixed on the 20 kilohm range. Results are then valid only at relatively low resistances where the test voltage is small.

A light-dependent resistor (opto-isolator) consists of a light-emitting diode (LED) and a photo-sensitive resistor, coupled optically inside an opaque package. Figure 25 shows a connection diagram for the DCX-127 and an LDR. DC output #1 is swept to vary current through the LED. A 1 kilohm series resistor produces a 1 milliampere/Volt relationship to the dc output #1. The DCX-127 ohmmeter measures the photo-sensitive resistance. To make the horizontal axis of the graph aproximately equal to LED current, DC output #2 was set to barely turn on the LED (about 1.4 Volts, as determined by monitoring the resistance) while DC output #1 was at zero volts. This approximately compensates for the "on" voltage of the LED. Figures 26 and 27 are the setup panels and a graph of this measurement. Note that LDRs can have long time constants (one second or greater) at high resistances and thus can require settling delay values of one second or more on the SWEEP SETTLING panel for accurate measurements.

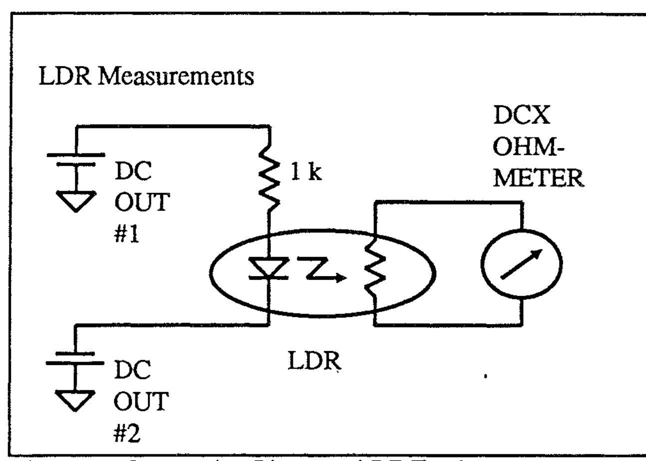


Figure 25 Connection Diagram, LDR Testing

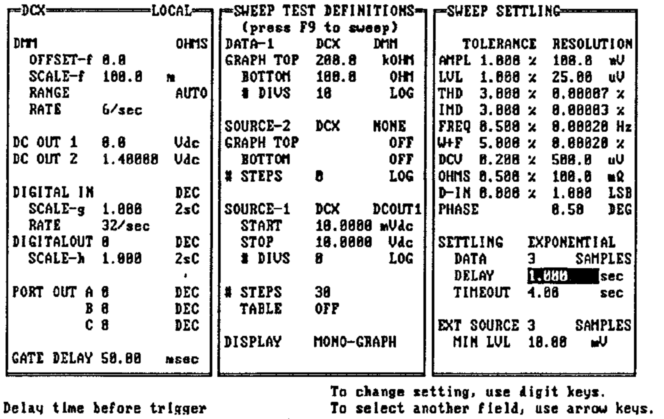


Figure 26 Setup Panels, LDR Tests

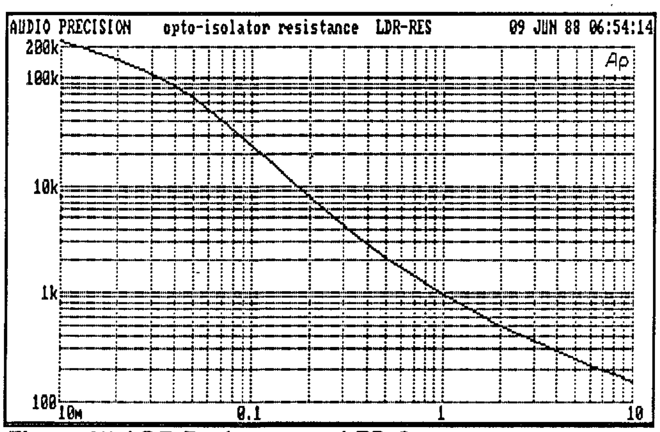


Figure 27 LDR Resistance vs LED Current

Digital Stimulus-DC Measurements: D-to-A Converter Testing

The value of the digital output word of the DCX-127 can also be varied during a test. Select DCX DIGOUT as SOURCE-1. Units may be selected as DEC (decimal), HEX (hexadecimal), or h(x) where the decimal value is scaled by the h-scale factor entered in the DIGITALOUT section of the DCX-127 control panel. START, STOP, and # STEPS values may be entered as desired to control the range and step size.

Data presented to the connector can be formatted in one of two formats; 8-4-2-1 BCD or two's complement (2sC), which is binary plus sign.

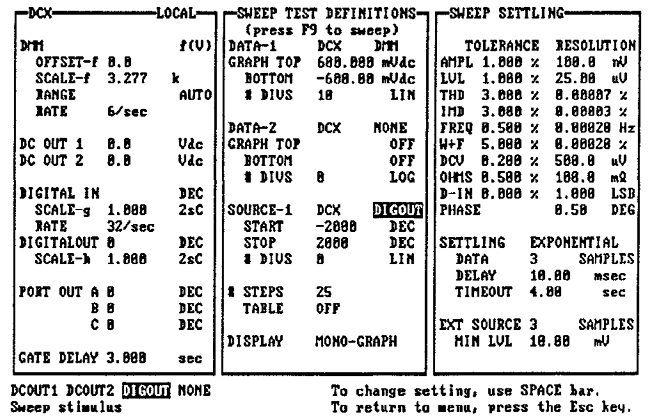


Figure 28 Setup Panels, D-A Converter Linearity Test

Static (dc) linearity testing of D-to-A converters is a principal application for digital stimulus and dc measurements. Note that dynamic testing is beyond the DCX capabilities, since the digital output update rate is limited to about 30 changes/second and the maximum dc meter reading rate is 25 readings/second (6/second for maximum resolution). Dynamic testing of converters is possible with the new DSP capability of System One; contact Audio Precision for more details. Figure 28 shows the control panel setup for a digital "sweep" around zero for a 16-bit D-to-A converter (full-scale range -32768 to 32768). Figure 29 is a graph from such a test. This setup is stored as D-TO-A.TST on the companion diskette.

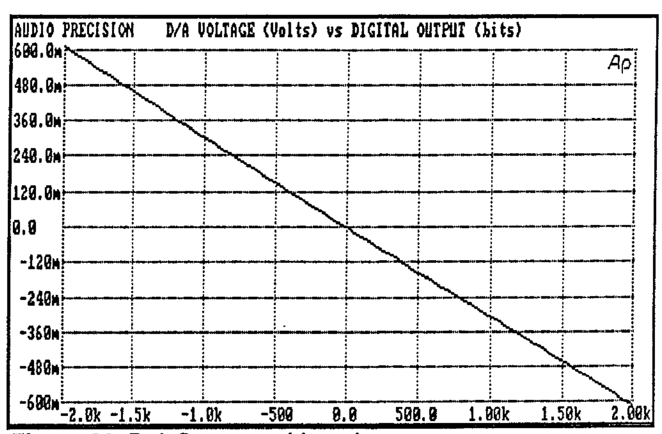


Figure 29 D-A Converter Linearity

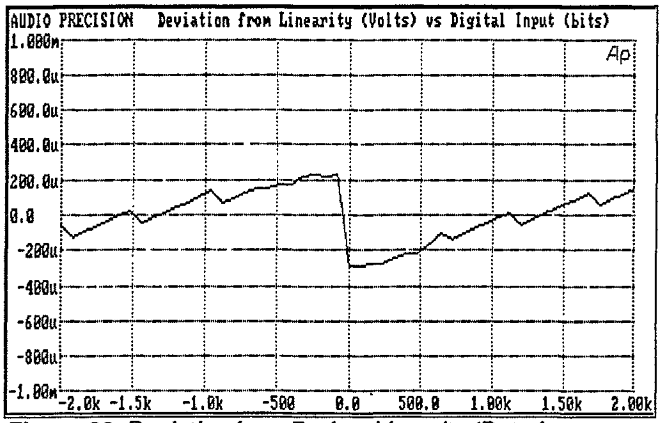


Figure 30 Deviation from Perfect Linearity (Data from Figure 29, Re-Graphed After Use of COMPUTE LINEARITY unction

COMPUTE LINEARITY Function

Linearity is difficult to accurately determine from a graph such as Figure 29 since it covers such a wide dynamic range. The limited pixel resolution of the PC display, in fact, obscures any small deviation from linearity which may exist.

S1 software contains a powerful COMPUTE LINEARITY menu command created expressly for such applications. Invoking this command causes a straight line to be created which is the best fit to the data or any specified sub-section of the data. Each data point is then subtracted from this straight line. Since this computation replaces the original data, the raw data should be saved via the Save Test command before COMPUTE LINEARITY is invoked if you wish to have further access to the original data. After using the COMPUTE LINEARITY command, the graph sensitivity may be greatly magnified by changing the GRAPH TOP and BOTTOM values at DATA-1. Figure 30 shows the data from Figure 29 after using the COMPUTE LINEARITY command and selecting new graphic coordinates to display the deviation from perfect linearity. Display system resolution is now not a limitation.

Limit files can be attached to D-to-A converter tests for use either before or after a COMPUTE LINEARITY calculation. Proper application of S1 software's limits capability for multiple-point tests requires an understanding of how it interpolates between points in a limit file in order to compare a data reading. At each data point, S1 software looks in the limit file for the nearest point with a higher SOURCE-1 value (to the right, in graphic terms) and the nearest point with a lower SOURCE-1 value (to the left). The software then performs an interpolation between those two limit file points in order to obtain a single value to which to compare the data point. If the SOURCE-1 (horizontal) values of both limit file points are positive, S1 software performs a logarithmic horizontal interpolation. If either point is zero or negative, logarithmic interpolation is not possible and a linear interpolation is performed. Similarly, the vertical (DATA-1 or DATA-2) interpolation is performed logarithmically if both points have positive vertical values and linearly if either is zero or negative.

In the case of D-to-A (and A-to-D) converters, logarithmic interpolation is rarely appropriate. If the converter is tested over a range which includes zero, linear interpolation is automatically forced by creating a limit file with only two points, one at the negative and one at the positive extreme. If the converter is tested across a range which is only positive on either the digital or dc axis, limit files must be created with sufficient intermediate points that the difference between logarithmic and linear interpolation is negligible. With tight limits, this may lead to a very high point density. It may also be possible to create a two-point limit file with one end below zero in order to force linear interpolation, even when all data will be at positive values. Limit testing after use of COMPUTE LINEARITY is probably a better solution in most cases.

For use before COMPUTE LINEARITY, upper and lower linearity limits must be diagonal lines. After COMPUTE LINEARITY, the data represents deviation from perfect linearity and the appropriate limit files may be simply horizontal lines. Depending upon the application, it may also be appropriate to have limits after COMPUTE LINEARITY which are tightest near zero and increase in both directions away from zero, in a "bow tie" or "butterfly" shape.

DC Meter Resolution Limitations

The resolution of the DCX-127 digital voltmeter depends upon which range is in use. Resolution on the 200 mV range is 10 microvolts, for example, while on the 20 Volt range it is one millivolt. A 16-bit D-to-A converter with a ±5 Volt dc output range, for example, has a theoretical transfer characteristic of 10 V/65536 states or about 152 microvolts output change for a one LSB change in input. At output values within ±200 mV of zero, the dc voltmeter resolution of 10 microvolts is thus more than adequate. At values greater than ±1.999 Volts, the meter will autorange to its 20 Volt range and the consequent one millivolt resolution will obscure errors smaller than approximately 6 LSBs.

Either of the DCX-127's dc outputs can be inserted with jumper leads in series with the dc voltmeter input and set to a value which offsets part of the converter's output voltage. This connection creates a differential voltmeter configuration which measures the difference between the output of the D-to-A converter under test and the DCX-127 dc output. If that difference is less than 200 mV, the meter can range to its most sensitive range and use its full resolution. To test a converter across its full range with adequate meter resolution in every case will thus require a series of test sweeps, each with a different value of dc output voltage for meter offset in order to keep the meter on a range with acceptably-high resolution.

DC Stimulus-Digital Measurements: A-to-D Converter Testing

Testing devices such as A-to-D converters is conceptually similar to D-to-A converter testing in many ways. Either of the dc outputs of the DCX-127 is used for stimulus, while the digital output of the converter is connected to the DCX-127 digital input.

On the control panels, SOURCE-1 is now selected as DCX DCOUT1 or DCOUT2 and appropriate voltage values entered for START, STOP, and # STEPS. At DATA-1, DCX DIGIN is selected. For graphic display, DEC (decimal) or g(x) (scaled decimal) may be selected as units, with any desired GRAPH TOP and BOTTOM. HEX (hexadecimal) notation may also be selected if tabular dis-

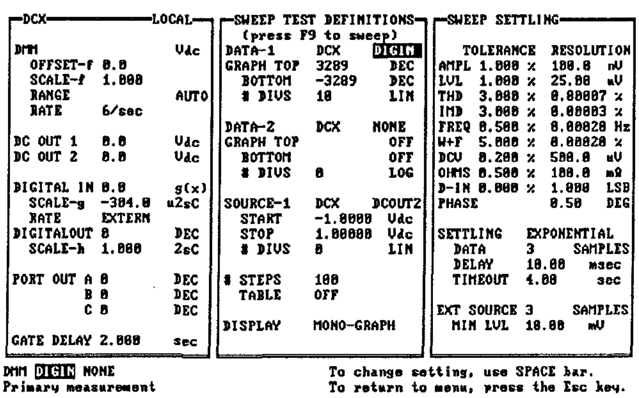


Figure 31 Setup Panels, A-D Converter Linearity Tests

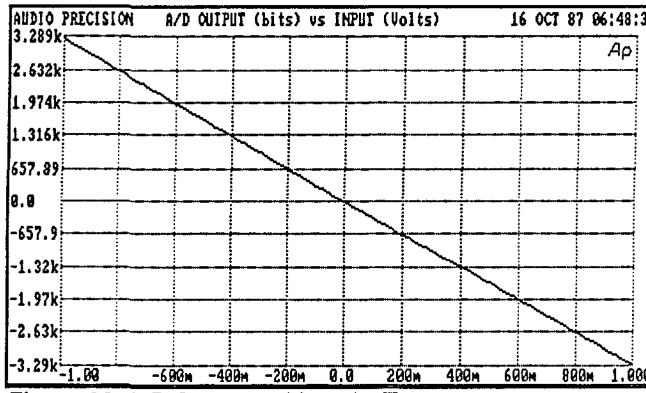


Figure 32 A-D Converter Linearity Test

play is selected at the bottom of the panel (DISPLAY TABLE at the bottom of the SWEEP TEST DEFINITIONS panel). Figure 31 is an example of a panel setup and Figure 32 the resulting graph from a test of an A-to-D converter. See A-TO-D.TST on the diskette for this test setup.

The COMPUTE LINEARITY function may be used for A-to-D converter testing in a manner analagous to D-to-A converter testing. See Figure 33 for a re-graph of Figure 32 after the COMPUTE LINEARITY operation.

Limit files may also be applied, with the same considerations as discussed earlier with regard to logarithmic vs linear interpolation. Note that S1's limit comparison is "less than or equal to". Therefore, a device passes a test if its output is exactly equal to the limit. Exact equality of measurement to limit is very unlikely when analog measurements are made and compared, but quite possible when digital devices are measured since the device output resolution and the DCX-127 input resolution are identical.

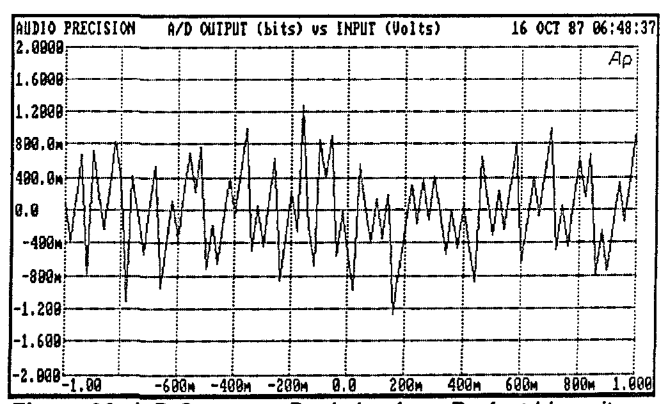


Figure 33 A-D Converter Deviation from Perfect Linearity

There is no analagous factor to different dc voltmeter resolution on different ranges when testing A-to-D converters with the DCX-127. The dc outputs have a constant resolution of 20 microvolts or better across their full range, and the digital input has a constant one LSB resolution.

Digital Stimulus-Digital Measurements

A digital device may be tested on a static (dc) stimulus-response basis with the DCX-127. Since it is unlikely that such devices will have a linear "digital transfer characteristic" across a range of contiguous digital states, most such tests are likely to be "spot" measurements. Thus, logic circuitry can be tested one state at a time by applying a specific digital stimulus while measuring and comparing to limits the digital output. Since a digital input-digital output device is likely to have only one correct output state for a given input, the upper limit and lower limit will typically be equal to one another and equal to the expected digital output word. A single limit file may thus be saved and named both as upper and lower limit.

The format flexibility of S1 software can simplify testing of certain digital interface circuits. Circuitry designed to drive BCD indicators can be easily tested by stimulating it with the DIGOUT signal in 2sC (two's complement, or binary) format while measuring the device's output with the DIGIN capability in BCD format.

Control and Communications with External Devices

The DCX-127 and S1 software provide capability for control of external devices via logic or by driving external relays. Additional control of external devices and synchronization of procedures with external devices is possible by S1 software features using ports of the PC.

Three 8-bit latched output ports are located on the rear panel of the DCX-127. Each is a 9-pin D subminiature connector. The bit pattern at each port is set in one of two fashions; by an entry on the DCX-127 panel, or by use of the UTIL OUT command of the menu.

The DCX-127 panel is normally used to set the digital word at a port when the application calls for the word to be different for each different test. Saving a test setup saves the words specified at all three ports, and loading a test restores all the conditions specified in that test. The word may be entered in the DCX-127 panel in either decimal (DEC), hexadecimal (HEX), or octal (OCT) format.

The UTIL OUT method of setting port values may be used when output conditions must be changed before a test is loaded or changed during an automatic procedure without loading another test. Only the decimal format may be used with UTIL OUT.

It is important to understand the priorities between the DCX-127 panel and the UTIL OUT command in controlling ports A, B, and C. When a test is loaded, the settings in the test (including a zero setting) take priority over the previous condition of the ports, whether that condition was established by a previous test file or by the UTIL OUT command. After a test has been loaded, exiting to the menu and using the UTIL OUT command will override the settings on the DCX-127 panel. Those changes will be visible on the DCX-127 panel after using UTIL OUT and returning to the panel. If the test file were saved at that stage, it would have the new settings stored in it.

The UTIL OUT command may also be used in connection with any port of the computer, such as its parallel printer port, serial (COM1 or COM2) port, or ports added by plug-in accessory cards. In this case, the port address (in decimal) is used rather than the A, B, or C designations for the connectors on the DCX-127.

The UTIL WAIT command can be used to synchronize an automatic procedure with a condition of an external device. The UTIL WAIT command is invoked with a computer port address, data word, and optional data mask. When a UTIL WAIT statement of a procedure is reached, the procedure will pause until the specified data word (logic condition) as qualified by the optional data word mask appears. In a typical application, UTIL OUT is used to command an external device to go to a certain condition. To obtain verification that the device has truly assumed the necessary condition, UTIL WAIT may then be used to sense some "ready" indication line of the device. When the device signifies that it is ready, the procedure moves on to its next line. See the User's Manual for more information and examples.

Overlays

If it is necessary to set the ports at some point in an automatic procedure and have those port conditions maintained during a succession of tests, S1 software's Overlay capability must be used. An overlay (.OVL) file is identical to a test (.TST) file except that one or more of the fields on the panel have been rendered inoperative by "punching them out". To punch out a field, such as the PORT OUT A field, place the cursor on that field and press <Alt>P. The video characteristics used to display that field will change, depending on the type of display system and monitor you have. When one or more fields have been punched out, the file may only be saved as an Overlay file by the Save Overlay command. When loaded, an overlay file functions identically to a test file except for the punched-out fields. Punched-out fields simply maintain the previous condition of that field. See the Overlay section of the Procedures chapter of the User's Manual for more details.

Replacing the Computer Keyboard

In Quality Assurance and production test applications, the operators of a test system are frequently not trained technicians or engineers. A PC keyboard may be unnecessarily complex for such operators, possibly intimidating them and producing error opportunities.

The computer keyboard may be hidden or entirely disconnected and replaced with a simple, user-furnished set of switches. The DCX-127 Program Control Input connector permits connection of up to eight normally-open switches. A momentary connection of any of these switches to ground causes a previously-recorded series of keystrokes to be executed. These keystrokes are stored as macro files (.MAC); different macro files may be created and loaded to give different functional definitions to the switches.

A macro may, for example, load and run a procedure which fully tests a given device and makes a go/no-go decision on its acceptability. With this type of usage, the computer monitor could even be eliminated and Pass/Fail could be indicated by lighted annunciators driven off DCX-127 ports A, B, or C. The operator's choices may be limited to "RUN TEST A", "RUN TEST B", and "HALT".

Switches could also be defined as equivalent to the four cursor control arrows, spacebar, <Enter> key, <Esc> key, and F1 (procedure abort) key. In this case, the operator would have full ability to load and run any procedure shown in the procedure directory, but without the error (or editing) possibilities of a full keyboard. See the Custom Keyboard section of the DCX-127 chapter of the User's Manual for more details.

Adding AC and Audio Test Capability

The DCX-127 provides only dc and digital stimulus and measurement capability. For applications which additionally require measurement of ac voltage, frequency, phase, harmonic and intermodulation distortion, wow and flutter, and generation of sinewaves up to 200 kHz, squarewaves, sine bursts, and white or pink noise, contact Audio Precision for additional information on the complete System One test system which is controlled from the same digital interface and software. The new DSP capability of System One will also permit dynamic testing of A-D and D-A converters.

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