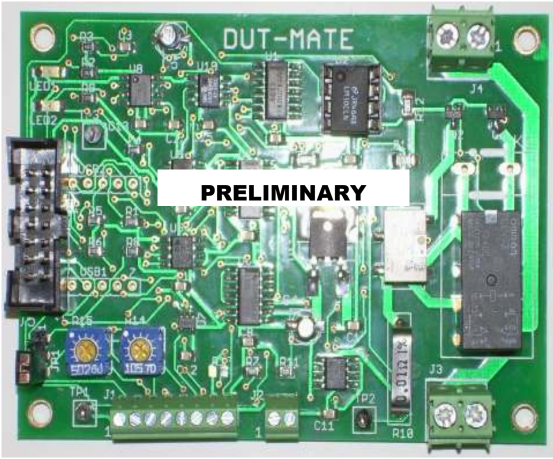
EMBEDDED TEST SOLUTIONS

DUT-MATE

Device-Under-Test
Power Control Module



USER'S MANUAL

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1. All products returned to OI for service, regardless of warranty status, must be on a freight-prepaid basis.
2. Unless otherwise noted, OI will repair or replace any defective product within 10 days of its receipt.
3. For in-warranty repairs, OI will return repaired items to buyer freight prepaid. Out of warranty repairs will be returned with freight prepaid and added to the service invoice.

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1. Introduction

1.1 Overview

What is fundamental to testing any electronic device, is the need to supply DC power. The DUT-MATE is a unique power control module that is used to deliver "safe" power to virtually any DUT, "Device-Under-Test". The DUT-MATE is offered in 3 different current ranges (1amp, 5amp and 10amp), and provides 3 separate control interfaces (Manual, Embedded and Computer).

The DUT-MATE is a key member of OI's, ETS Series - EMBEDDED TEST SOLUTIONS. The ETS Series is a smart collection of (hardware and software) tools that are designed to reduce the high Cost-of-Test, while providing Test Engineers greater flexibility and more opportunities to apply test automation.

The DUT-MATE performs (5) critical functions:

Short Sensor — The DUT-MATE contains a special electronic sensor that is used to detect a short-circuit (which may be located on the DUT power-rails). By checking for "shorts" prior to applying power, the DUT-MATE prevents damage to the device-under-test, the adjoining test equipment and possible injury to the test Operator.

Versatile Power Switch — The DUT-MATE provides a DPDT Relay to switch power to the DUT. The relay is offered in 3 different current ranges (1amp, 5amp or 10amp). There are also 3 methods for switching power, Manually (external toggle switch), Embedded (microcontroller), or via PC (optional USB interface).

Over-Current Detector — The DUT-MATE has an adjustable circuit-breaker. Once power is applied to the DUT, the circuit-breaker provides a safeguard to avoid over-current conditions. An on-board potentiometer or a remotely settable DAC circuit is used to establish a set-point which limits the output current.

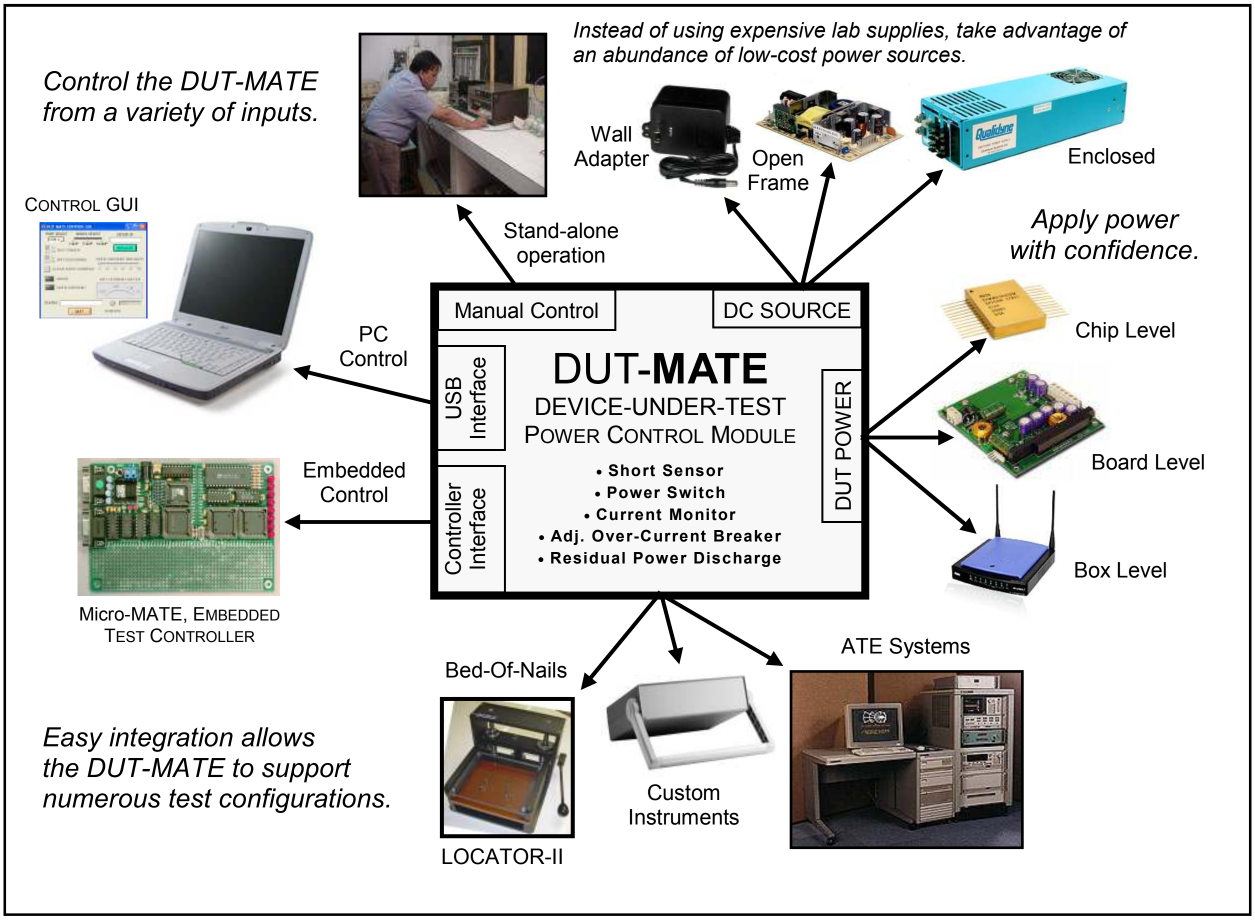
Current Monitor — The DUT-MATE includes a current measurement circuit, which generates a voltage that is proportional to the current-drain. An ADC circuit converts the voltage to a 16 bit word which can be remotely 'read back'.

Residual Voltage Discharge — The DUT-MATE offers a second relay that is tied across the DUT power rails to provide a residual voltage discharge function. This feature is important because it ensures any lingering voltages are completely removed from the DUT, before power is applied.

1.2 Highlights

BENEFITS	APPLICATIONS	FEATURES
• *A flexible, low-cost alternative to traditional Lab power supplies* • *Combines (4) power control functions into a single module* • *Can be used in stand-alone or fully automated test equipment* • *Great for embedded solutions, place inside mechanical test fixtures, instrument boxes or rack-mount enclosures*	• *Safely apply power to Semiconductors, Hybrid Modules, Printed Circuit Boards, Box-level units or full systems* • *Burn-In* • *Engineering* • *Depot Repair* • *Production Test* • *QA/QC Quality Control* • *OEM Test Instruments*	• *DUT current monitor* • *A programmable circuit breaker* • *A discharge circuit to remove residual voltage* • *LED's indicate active relays* • *A choice of (3) models - 1Amp, 5Amp & 10Amp* • *Support for Manual, Computer or Embedded control* • *Compact size, a 2.5" x 3.5" PCB, with four #4 mounting holes in each corner (spacers and hardware included)*

1.3 Solutions



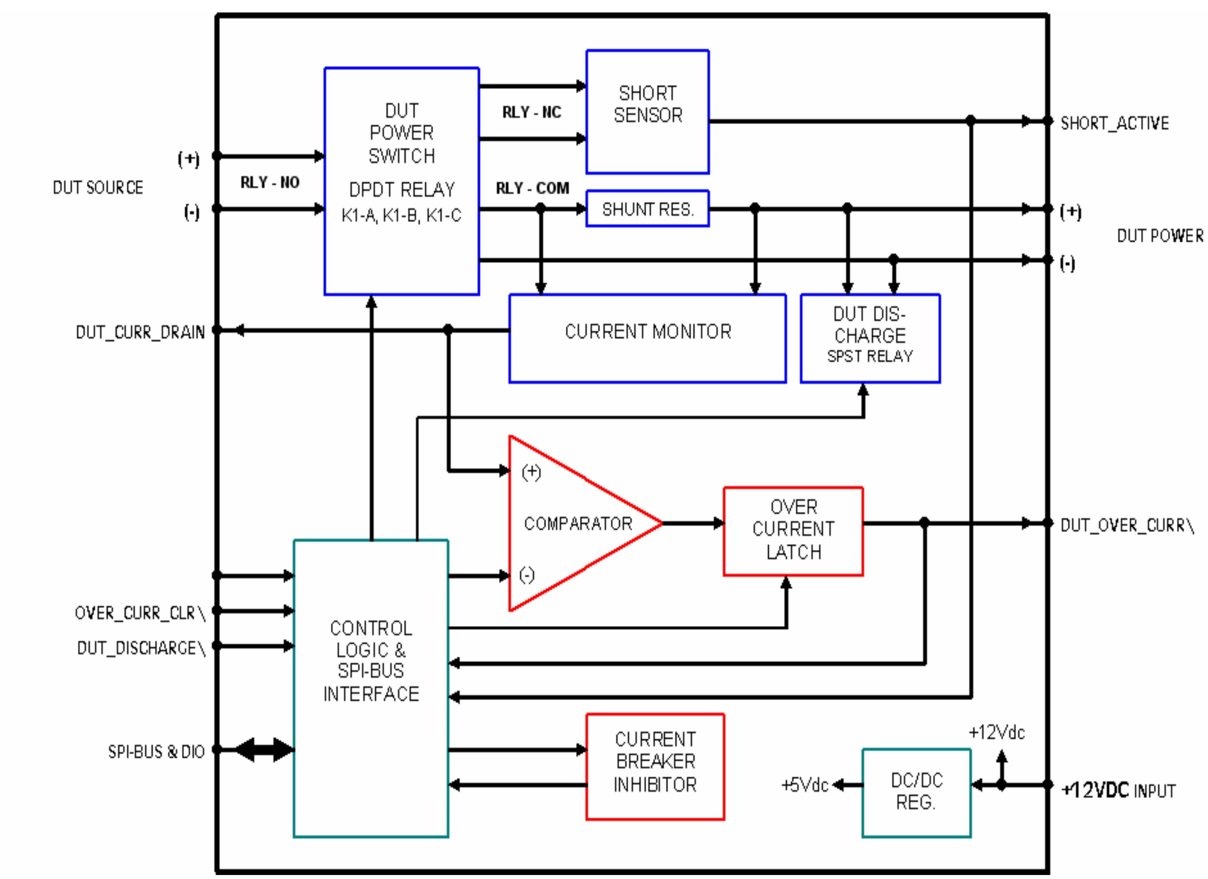
1.4 Specifications

MODEL	0701	0702	0703
Power (max)	30W	150W	300W
Load Switching Voltage (max) Current (min) Current (max)	 30Vdc 10uA 1A	 30Vdc 10mA 5A	 30Vdc 100mA 10A
Over-Current Limit, Programming Accuracy (25ºC±5º)	0.1% FS		
Current Read-Back Accuracy (25ºC±5º)	0.1% FS		
DUT Current Drain Output	0-1.0Vdc FS		
Variable Over-Current Detection Delay	~ 0 - 1.5sec		
Control Interface	Manual	J1(9-pin terminal)	
	Embedded	J5(14-pin header)	
	Computer	USB Interface	
DC Input	12Vdc, 1Amp		
Operating Environment	0 - 50º, 80% RH		
Weight	xxxkg		
Dimensions	2.5" W x 4.0" L		

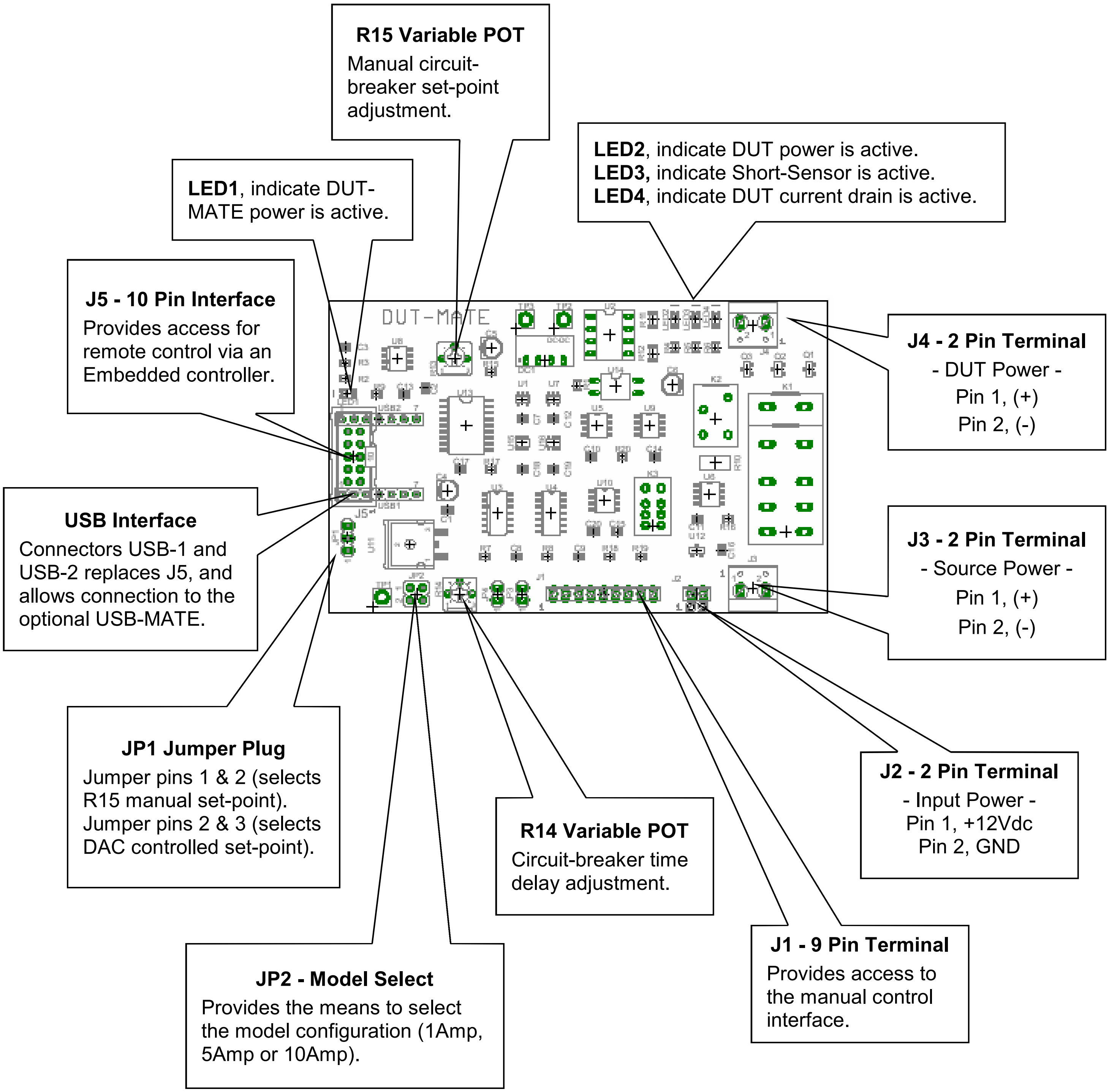
2. Description

2.1 Block Diagram

The major circuit functions that comprise the DUT-MATE are represented in the block-diagram below. The 'blue' colored circuit blocks relates to the delivery of DUT power (which includes the DUT power switch, the current monitor and the DUT discharge relay). The circuit in 'red' highlights the over-current circuit breaker function. And finally, the DUT-MATE input power and control logic functions are shown in the 'green' blocks.



2.2 Board Layout



2.3 Connections

J1

Pin	Name	Dir.	Description
1	DUT_PWR_ENA\	→	A TTL active-low 'input' signal that controls a DPDT relay which applies output power to the DUT.
2	DUT_OVER_CURR\	←	A TTL active-low 'output' signal that indicates the over-current limit is 'set' or 'clear'.
3	OVER_CURR_CLR\	→	A TTL active-low 'input' signal that resets the over-current circuit breaker.
4	SHORT_ACTIVE	←	A TTL active-high 'output' signal that indicates a short-circuit condition
5	DUT_DISCHARGE	→	A TTL active-low 'input' signal that controls the SPST relay which applies a short across the input power-rails on the DUT.
6	DUT_CURR_DRAIN	←	A 0-1Vdc output voltage that represents the DUT current drain.
7	CHK_SHORT\	→	A TTL active-low 'input' signal that controls a SPST relay that activates the Short-Sensor.
8	VCC_OUT	←	A regulated +5Vdc output for external use. Current limited to roughly 100mA.
9	GND	←	Ground

J2

Pin	Name	Dir.	Description
1	+12Vdc	→	A regulated +12Vdc input .
2	GND	→	Ground

J3

Pin	Name	Dir.	Description
1	Source Pwr (+)	→	DUT Source Pwr (+)
2	Source Pwr (-)	→	DUT Source Pwr (-)

J4

Pin	Name	Dir.	Description
1	DUT Pwr (+)	←	DUT Input Pwr (+)
2	DUT Pwr (-)	←	DUT Input Pwr (-)

2.3 Connections, cont.

J5			
Pin	**Name**	**Dir.**	**Description**
1	N/A		
2	SCLK	→	Part of a 3-wire SPI-Bus, SCLK synchronizes the serial data transfer for the DIN and DOUT signals.
3	RST\	→	A TTL active-low "input' signal that provides a reset to the DIO circuit.
4	DIN	→	Part of a 3-wire SPI-Bus, DIN is serial command and control data for the, ADC, DAC and DIO circuits.
5	INT	←	A TTL active-low "output' signal that indicates an interrupt from the DIO circuit.
6	DOUT	←	Part of a 3-wire SPI-Bus, DOUT is serial output data from the ADC and DIO circuits.
7	DIO_CS\	→	A TTL active-low "input' signal that provides a chip-select for the DIO circuit.
8	DAC_CS\	→	A TTL active-low "input' signal that provides a chip-select for the DAC. The 12-bit DAC, sets the over-current-limit.
9	GND	←	Ground
10	ADC_CS\	→	A TTL active-low "input' signal that provides a chip-select for the ADC..

3. Operation

3.1 Manual Control

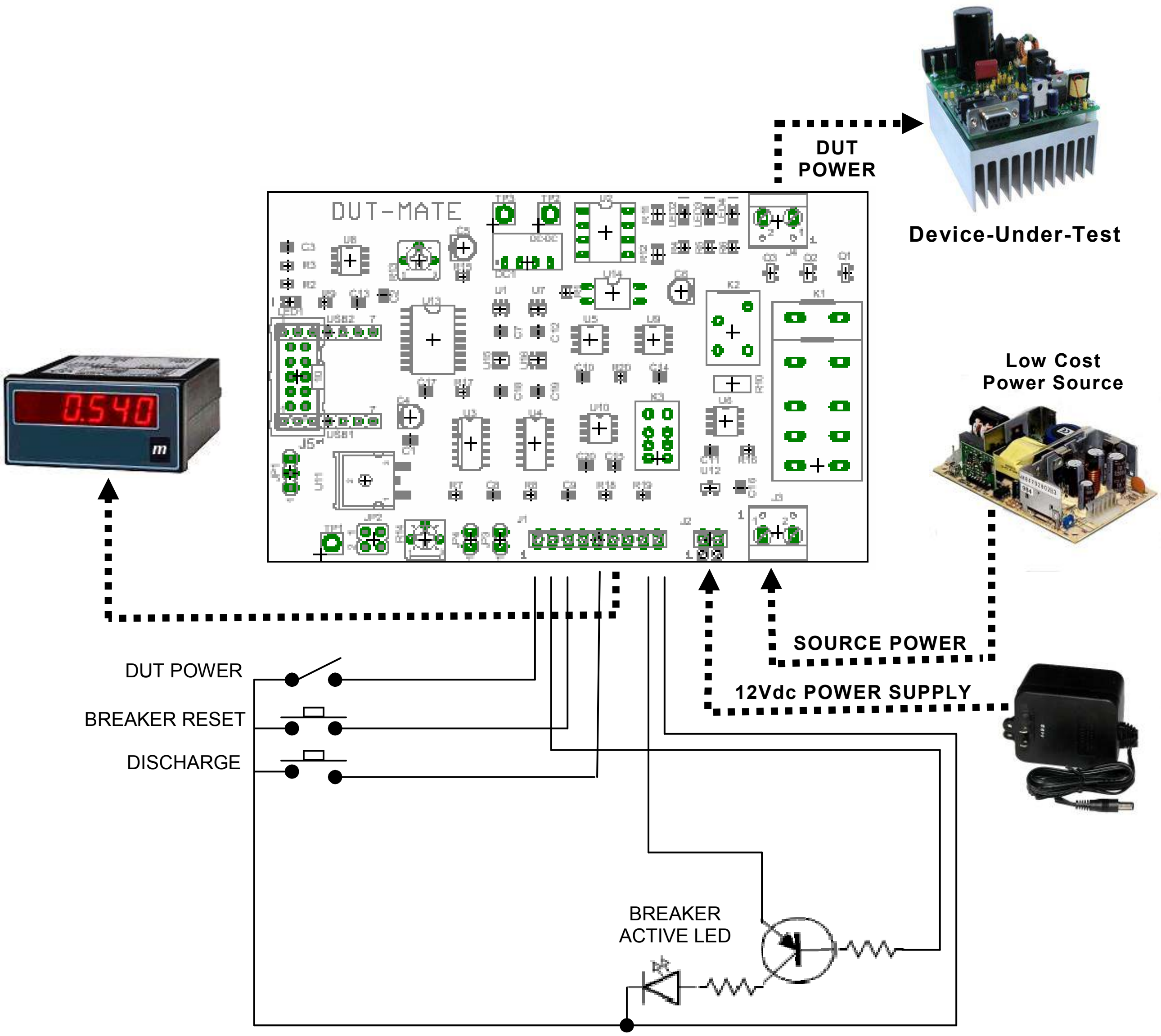
To reduce cost and improve performance, the DUT-MATE can often be used in-place of traditional "lab" Power Supplies. In section 3.1.1 (on the next page), the diagram shows the wiring connections required to configure the DUT-MATE for Manual (stand-alone) operation. Rather than using an expensive Power Supply to power the Device-Under-Test, the DUT-MATE (and the surrounding circuits), could easily be built into a low-cost instrument box or enclosure. In addition, the enclosure could also house other circuits that may be needed to exercise the DUT as well. The DUT-MATE makes it possible to integrate the entire test solution into a single test instrument.

In the diagram, the DUT-MATE is shown supplying power to a typical electronic assembly. A low-cost DC wall adaptor and a open-frame power supply are used to power the DUT-MATE and the DUT (through connectors J2 and J3 respectfully). Manual operation is supported by a set of 3 switches (a toggle switch and 2 momentary push-button switches), as well as a status LED and a Digital Panel Meter. As shown in the diagram, primary control of the DUT-MATE takes place through connector J1. A table (below the diagram), is also provided to further detail the circuit connections related to J1.

As part of the set-up process make sure the jumper-plug is installed on JP1 (pins 2 & 3). This will allow the over-current circuit-breaker to be manually adjusted. The circuit-breaker set-point is set by potentiometer R15, which is a single turn pot. In the fully counter-clockwise position, R15 sets the circuit-breaker to near zero (which means the circuit-breaker will likely trigger with minimum DUT current flow). As R15 is adjusted in the clockwise direction, this increases the amount of current flow the DUT-MATE will allow before the circuit-breaker is triggered. Generally, R15 works as a 0-100% adjustment (with 100% representing the maximum current). To counter-act the effects of the initial power surge by the DUT (which tends to cause the circuit-breaker to prematurely trip), the DUT-MATE employs a special timing circuit that suspends the over-current measurement circuit for a period of time. The time period is varied by pot R14, which creates a delay from roughly 10msecs (R14 fully counter-clockwise) to roughly 1500msecs (R14 fully clockwise). When starting out it is best to set R14 and R15 to their mid-points and then adjust accordingly.

Set the DUT Power switch to the OFF position. When an active +12Vdc source is connected to J2, LED-1 on the DUT-MATE should turn ON (which indicates the DUT-MATE is ready for use). If the Breaker Active LED is ON, then momentarily press-and-release the Breaker Reset switch and the Breaker Active LED should turn OFF. To remove any residual DUT voltage, press (for roughly 1 second) and then release the Discharge switch (LED-4 on the DUT-MATE should turn ON and then OFF). Finally, set the DUT Power switch to ON position and observe LED-2 on the DUT-MATE is turned ON. Depending on the load of the DUT, you should also see a current reading on the Digital Panel Meter.

3.1.1 Manual Configuration

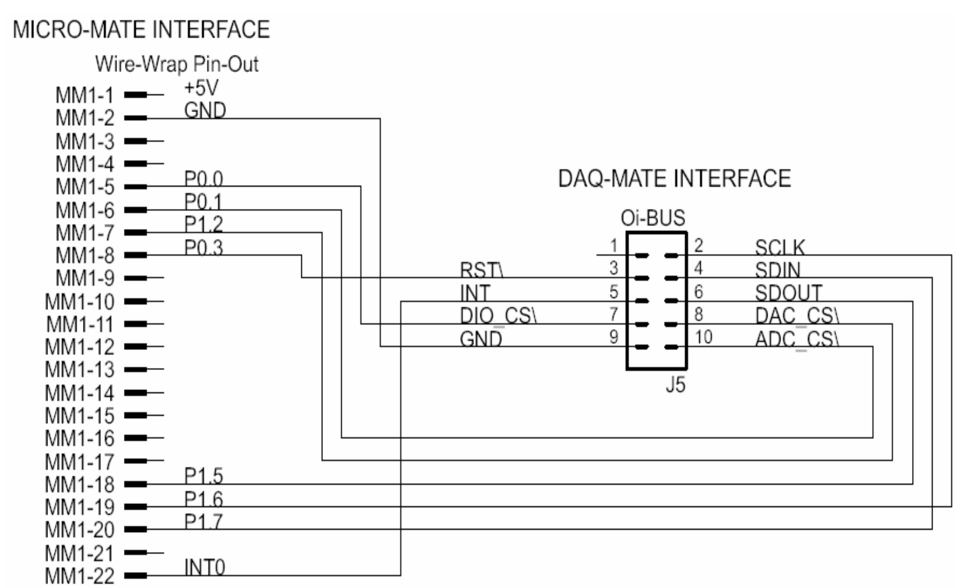


PIN	MEMONIC	I/O TYPE	FUNCTION
J1-1	DUT_PWR_ENA\	SPST SW	DUT POWER
J1-2	DUT_OVER_CURR\	LED	BREAKER ACTIVE
J1-3	OVER_CURR_CLR\	Push Button SW	BREAKER RESET
J1-5	DUT_DISCHARGE	Push Button SW	DISCHARGE
J1-6	DUT_CURR_DRAIN	METER	CURRENT METER
J1-8	VCC_OUT	Circuit Bias	VCC
J1-9	GND	GND	GND

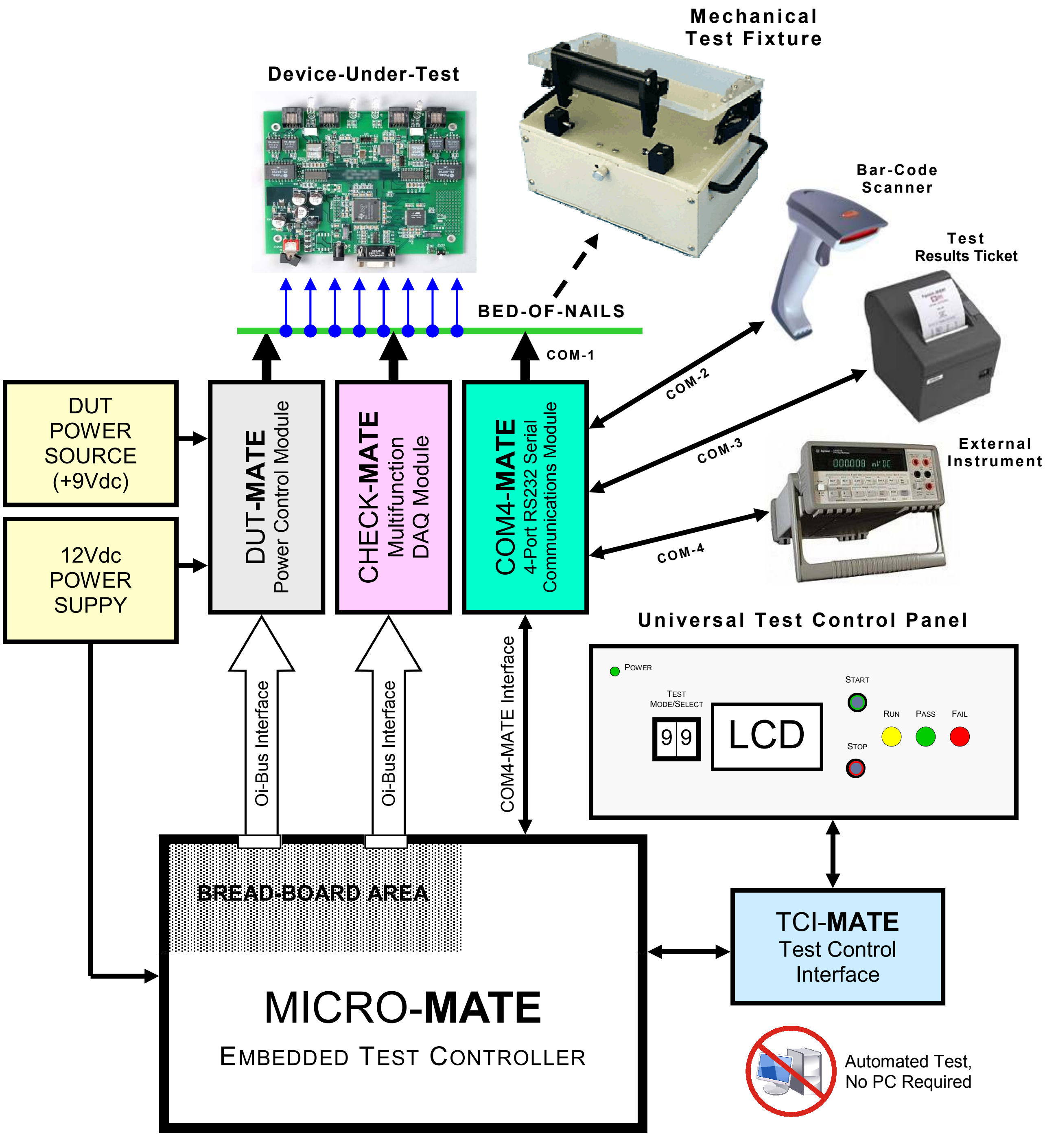
3.2 Embedded Control

In section 3.2.1 (on the next page), the DUT-MATE is shown integrated with other ETS Series components that collectively form a complete Embedded Test Solution. The diagram shows the DUT-MATE being driven by the Micro-MATE. The Micro-MATE is a low-cost "Embedded Test Controller", which stores a special program that is designed to exercise the device-under-test and generate Go/No-Go test results. The Micro-MATE also provides a sizable breadboard area to support the development of custom circuits. Adjacent to the breadboard area is a series of wire-wrap pins that comprise a goodly amount of general purpose Digital I/O. The schematic below shows the wire-wrap connections which create the Oi-BUS interface between the Micro-MATE and the DUT-MATE (J5, 10-pin header connector).

Actually the DUT-MATE can be easily driven by most microcontrollers (including an ARM, AVR, PIC or even a STAMP). When developing an interface for the DUT-MATE, it is recommended the designer start-by reviewing the interface requirements as outlined in the J5 Table (which is provided in the Connections section). The next step is to review the DUT-MATE schematic, which is provided in Appendix B. What could be the most challenging aspect of the design effort is controlling the SPI-bus devices. The DUT-MATE contains 3 SPI-bus devices which include an ADC, DAC and DIO circuits. The ADC is used to measure the DUT current flow and is a Maxim (part number MAX1241). The DAC is used to set the circuit-breaker current limit and is a MicroCHIP device (part number MCP4921). The DIO is an 8-bit device from MicroCHIP (part number MCP230S08), and is used to control various DUT-MATE functions. Details for specific device performance and SPI-bus operation can be found in their respective data sheets. Go to the manufacturers website to download said documents.



3.2.1 Embedded Configuration



3.2.2 Embedded Programming

To build-on the PCB board test example (shown in section 3.2.1), we have constructed a demo program using BASCOM. BASCOM is a BASIC language compiler that includes a powerful Windows IDE (Integrated Development Environment), and a full suite of "QuickBASIC" like commands and statements. The demo program (which is outlined in section 3.2.3), illustrates the ease of controlling the DUT-MATE via the Micro-MATE microcontroller.

The program starts by initialing the Micro-MATE for proper operation. You will note that the BASCOM software provides excellent bit-manipulation capabilities, as evident by the use of the ALIAS statement. The Micro-MATE (P1 port bits) are assigned unique label names (i.e., SCLK, DOUT), which are used to support various DUT-MATE functions. In the "Main" program section, the Micro-MATE receives "high level" serial commands from a host PC, parses them and then executes accordingly. When (for example), the "DT_DP1" command is entered, the "Dut_pwr_on" subroutine is called, DUT power is switched-ON and the program returns a OK response. Next, the "DT_DM?" command is entered, the "Dut_rd_curmon(adc_val)" subroutine is called, the 16-bit ADC is measured and the program returns a hex string (which represents the DUT current drain).

Independent of the microcontroller hardware or programming language you choose, the program sequence described above will likely resemble the way you implement your DUT-MATE application. For this reason, we suggest that you go to our website and download the "DUT-MATE.zip" file. In the Documents folder will contain more extensive examples of routines to control the DUT-MATE.

3.2.3 Embedded Program Example

```
' Program: DUT-MATE Demo
'
---[ Initialization ]------------------------------------------------------------
'
$large
$romstart = &H2000
$default Xram

Dim A_num, A_byte, A_cnt As Byte
Dim S As String * 10, A_resp AS String * 10, A_str AS String * 10
Dim A_word as Word
Dim A_val as Single
Dim True As Const 1
Dim False As Const 0
Dim Ppi1_addr As Const &HF803    ' first 8255 chip configuration
Dim Porta_addr As Const &HF800   ' port A

Sclk Alias P1.0                  ' SPI-bus serial clock
Dout Alias P1.1                  ' SPI-bus serial data output
Din Alias P1.2                   ' SPI-bus serial data input
Dac_cs Alias P1.4                ' DAC chip select
Adc_cs Alias P1.5                ' ADC chip select
Oc_bit Alias P1.6                ' Over_Current status bit

Declare Sub Print_ic             ' print invalid command
Declare Sub Print_orr            ' print out-of-range
Declare Sub Print_ur             ' print under range
Declare Sub Print_ok             ' print command is OK
Declare Sub Dut_pwr_on           ' turn DUT power ON
Declare Sub Dut_pwr_off          ' turn DUT power OFF
Declare Sub Dut_rd_curmon(adc_val As Single)  ' read 20-bit ADC

---[ Main ]------------------------------------------------------------
' In the Main the Operator or Host, is prompted to enter a command.  The command
' is parsed and then executed if valid.  Only two command examples are shown.

Out Ppi1_addr , &H80             ' port A output
Out Porta_addr , &HFF            ' port A bits high
Set Sclk, Dout, Adc_cs, Dac_cs, Short_chk    ' Set to logic '1'
Do
  Input "Enter command " , S
  S = Ucase(s)
  A_resp = Left(s , 3)
  If A_resp = "DT_" Then
    A_resp = Mid(s , 4 , 2)
    Select Case A_resp

      Case "DP":                 ' set DUT power, DT_DPx, x=1 or 0
        A_resp = Mid(s , 6 , 1)
        A_num = Val(a_resp)
        If A_num = 0 Or A_num = 1 Then
          If A_num = 1 Then Call Dut_pwr_on    ' Enable DUT Power
          If A_num = 0 Then Call Dut_pwr_off   ' Disable DUT Power
          Call Print_ok          ' valid command
        Else
          Call Print_ic          ' invalid command
        End If

      Case "DT":                 ' read Current Monitor, DT_DM?
        A_resp = Mid(s , 6 , 1)
        If A_resp = "?" Then
          Call Dut_rd_curmon(adc_val)          ' read 20-bit ADC
          A_byte = 0, A_byte.0 = Adc_val.20, A_byte.1 = Adc_val.21 ' ADC status
          If A_byte = 2 Then
            Shift Adc_val , Right , 4
            A_word = Adc_val And &H0000FFFF
            A_str = Hex(a_word)
            Print "<" ; A_str ; ">"    ' print HEX results
          Elseif A_byte = 3 Then
            Call Print_oor       ' out-of-range
          Elseif A_byte = 1 Then
            Call Print_ur  ' under-range
          Else
          End If
        Else
          Call Print_ic          ' invalid command
        End If

      Case Else
        Call Print_ic            ' invalid command
      End Select
    Else
      Call Print_ic              ' invalid command
    End If
  Loop
End

'---[ Sub-Routines]------------------------------------------------------------
'
Sub Print_ic                     ' print invalid command
  Print "><"
End Sub

Sub Print_oor                    ' print out-of-range
  Print ">>"
End Sub

Sub Print_ur                     ' print under range
  Print "<<"
End Sub

Sub Print_ok                     ' print command is OK
  Print "<>"
End Sub

Sub Dut_pwr_on                   ' turn DUT power ON
  A_byte = Inp(porta_addr)       ' get Port-A byte
  A_byte.0 = 0                   ' reset DUT power control bit
  Out Porta_addr , A_byte        ' enable DUT power
  Waitms 100                     ' let relay settle
End Sub

Sub Dut_pwr_off                  ' turn DUT power OFF
  A_byte = Inp(porta_addr)       ' get Port-A byte
  A_byte.0 = 1                   ' set DUT power control bit
  Out Porta_addr , A_byte        ' disable DUT power
  Waitms 100                     ' let relay settle
End Sub

Sub Dut_rd_curmon(adc_val As Single)   ' read 20-bit ADC
  Adc_val = 0
  Reset Sclk
  Reset Adc_cs                   ' enable ADC chip-select
  Delay
  Do
  Loop Until Din = 0             ' check conversion complete bit
  For A_cnt = 23 Downto 0        ' generate 24 clock cycles
    Set Sclk
    Delay
    Adc_val.A_cnt = Din          ' receive serial bit stream
    Reset Sclk
    Delay
  Next A_cnt
  Set Adc_cs                     ' disable ADC chip-select
End Sub
```

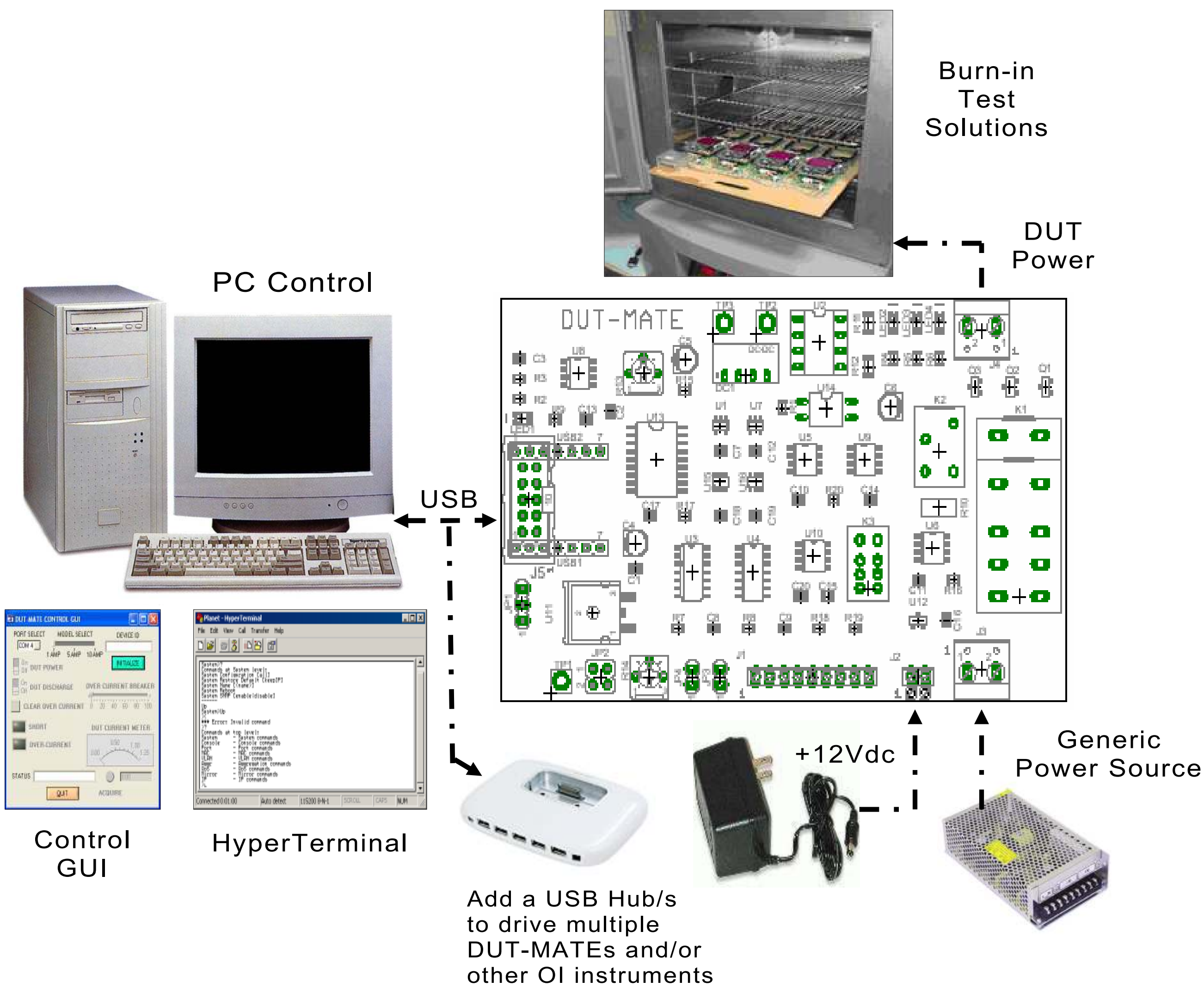
3.3 PC Control

For those who are more comfortable building traditional PC-based "Automated Test Equipment" (ATE), the DUT-MATE offers many features that are well suited for that environment as well.

Controlling the DUT-MATE from a PC, requires that it be equipped with an optional USB-MATE module. The USB-MATE module contains a USB-to-UART bridge chip and a PIC microcontroller. On the PC side, the USB bridge-chip receives a special set of serial commands. On the DUT-MATE side, the PIC controller processes the serial commands and then drives the DUT-MATE accordingly. In order to be recognized by the PC, the USB-MATE module requires a set of Windows' drivers be installed. To do so, go to "www.DUT-MATE.info", click "Download", select the "OI VCP Interface" file and follow the prompts. The letters VCP stands for "Virtual COM Port", and is a method by-which the USB interface can appear to the PC as a standard serial COM port. With the drivers installed and USB-MATE connected to the PC, go to the Device Manager (click on Ports) and verify "OI Serial Interface (COM#)" is included.

3.3.1 PC Configuration

The diagram below provides a basic illustration of a PC-driven configuration. As shown, the Burn-In chamber can accommodate multiple DUT's, in which case the DUT-MATE can apply power to all units simulteously (or each unit can be controlled individually). In a multiple DUT-MATE configuration, the designer would simply add a USB hub (or hubs) to the mix. As the chamber temperature cycles, the advantage is the PC can command the DUT-MATE to cycle power at timed-intervals. During the test process the PC can also record and monitor the current flow for each DUT as well.

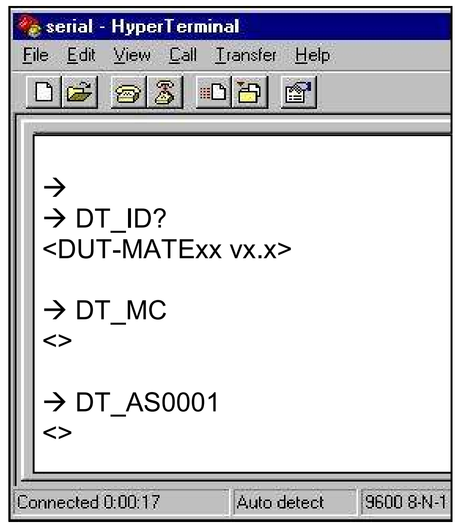


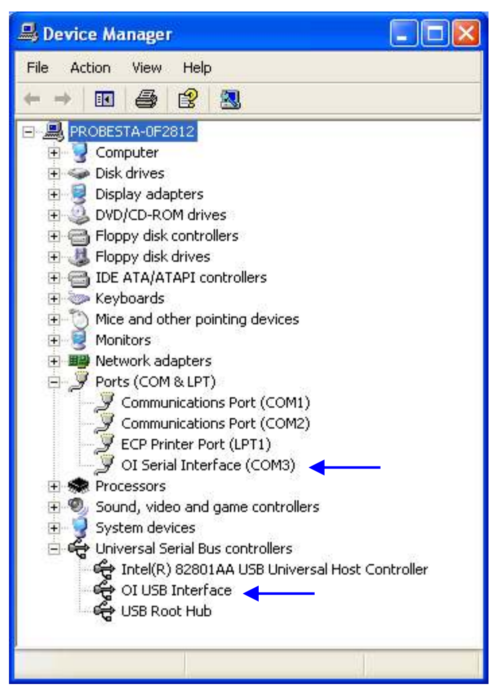
3.3.2 PC Programming

The starting point for developing code to control the DUT-MATE, begins with acquainting yourself with its Serial Command Set. The serial commands are a set (or group) of ASCII characters that originate from the PC and are designed to instruct the DUT-MATE to perform specific functions. The complete serial command set is detailed in Appendix B. There are two ways to exercise the serial commands, (1) using HyperTerminal or (2), run our Virtual Instrument Panel software (GUI Control).

3.2.1.1 HyperTerminal

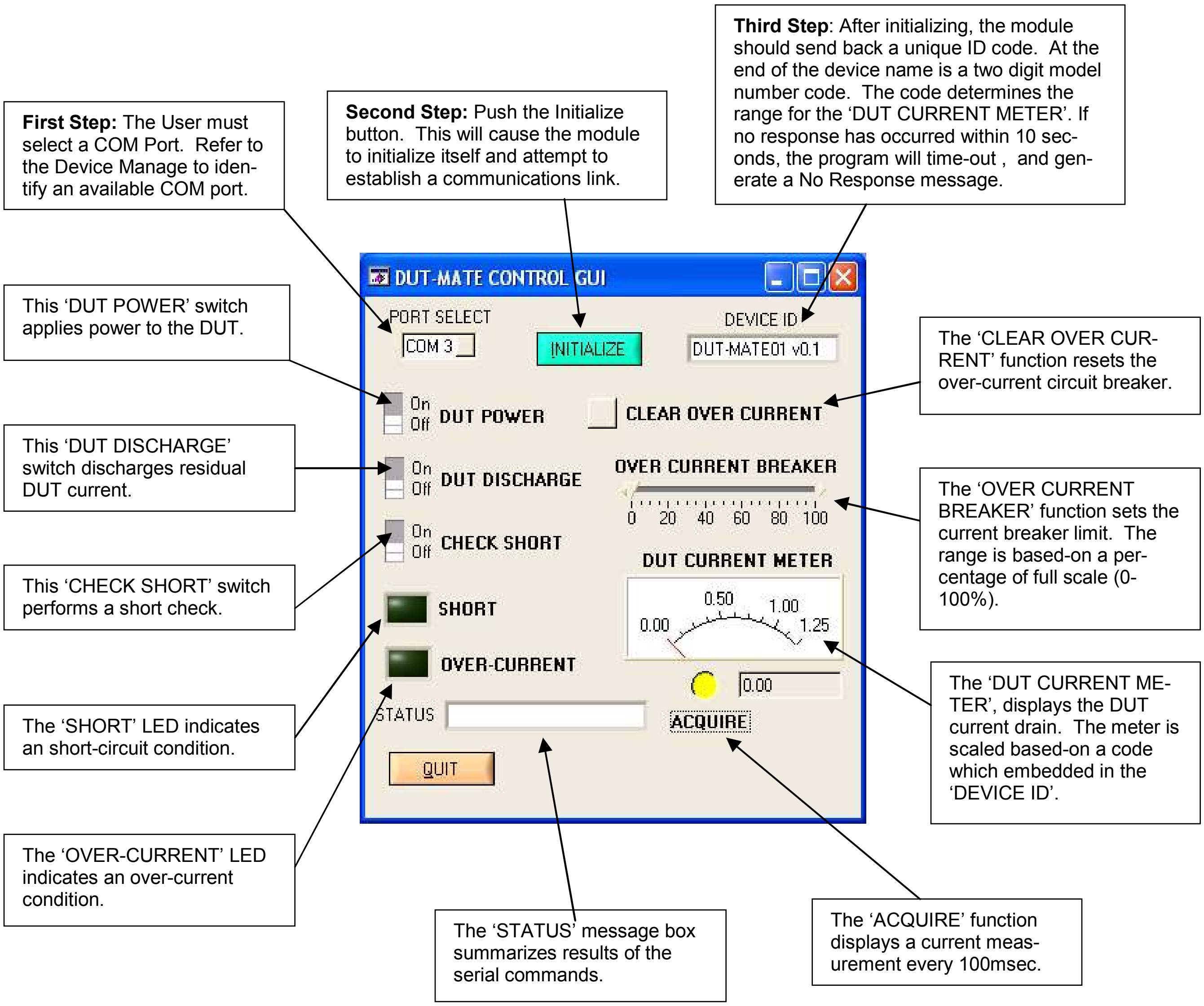
HyperTerminal is a serial communications program that comes with the Windows OS and is located in the Accessories folder. Use the USB cable to connect the PC to the DUT-MATE. Run HyperTerminal and configure the settings for 19200 bps, 8 data bits, no parity, 1 stop bit and no flow control. Select the COM port based on the available COM port as indicated in the Device Manager (example shown below). Press the ‘Enter’ key and the ‘→’ prompt should appear on the screen (as demonstrated in the example on the right). Refer to the table in Appendix B, to begin to experiment with the serial commands.





3.2.1.2 Virtual Instrument Panel

The Virtual Instrument Panel (or Control GUI), removes the hassle of "manually " typing ASCII commands and provides the User a more efficient method to interact and control the DUT-MATE. Download the panel from our website at www.dut-mate.info, click on downloads and select "Dut-Matexxx.exe".



3.2.1.3 PC Programming Example

```
//  DUT-MATE programming example in 'C'
//
//  The following program supports testing up to '8' electronic assemblies
//  (which are housed in a Burn-In chamber).  Testing will occur at three tem-
//  perature set-points  (25ºC, 50ºC & 0ºC).  Each electronic assembly will be
//  powered by a separate DUT-MATE instrument.  The objective for the test
//  is to automatically 'cycle' DUT power, and then read and store DUT cur-
//  rent measurements to a disk file.  However before DUT power is applied,
//  the program monitors the 'temp ready bit' to ensure the chamber has
//  reached the desired temperature.  When the temperature is stable, data is
//  collected once every second (for '1' hour), and then the next temperature
//  set-point is selected (and the cycle is repeated).  The program controls
//  the eight DUT-MATE's via an '8' port USB Hub.  The digital I/O control is
//  provided by the first DUT-MATE.  Also, during the test process, the tem-
//  perature impact could cause the DUT to trip the over-current circuit
//  breaker.  If so, the program will log the event and suspend the DUT
//  from further testing.

define      MSWIN       //  serial comm libraries from
#define     MSWINDLL    //  www.wcscnet.com

#include <comm.h>
#include <stdlib.h>
#include <stddio.h>
#include <time.h>

int stat, port=0, dio_com_port=0, mark_cnt_0=0;
int mark-cnt_1=1, a_byte=0, a_cnt=0, idx = 0;
Int dio_bit[10], port_num[16];
int True = 1, False = 0;
char dio_byte[10], dir_byte[10], char a_str[16];
char send_data[64], char read_data[64];

char auto_sequence[] = "DT_AS";      // auto DUT power sequence
char get_device_id[] = "DT_ID?";     // get device ID
char clear_over_current[] = "DT_OC"; // clear over current
char get_over_current[] = "DT_DO?";  // get over current status
char get_dut_current[] = "DT_CM?";   // get DUT current reading
char set_dut_power[] = "DT_DP";      // set DUT power On/Off
char master_clear[] = "DT_MC";       // master clear

main()
{               // Identify & initialize valid COMM ports
  port_active = False;
  dio_com_port = -1;
  for (idx = 1;  >= 16; idx++) {
    if ((stat = IsPortAvailable(idx)) == 0)  {
      port_num[idx] = -1;    // port not available
      continue;
    }           // Open COM ??, rx_buff = 256 bytes, tx_buff = 64
    port_num[idx] = OpenComPort(idx,256,64);
    port = port_num[idx];
    if (dio_com_port == -1) dio_com_port = port;
    SetPortCharacteristics(port,BAUD19200,PAR_EVEN,
              LENGTH_8,STOPBIT_1,PROT_NONNON);
    CdrvSetTimerResolution(port,1);      // 1 msec ticks
    SetTimeout(port,2000);               // 2 sec time-out period
    FlushReceiveBuffer(port);            // clear receiver buffer
    FlushTransmitBuffer(port);           // clear transmit buffer

    sprintf (send_data, "%s\r", "");  // Get device prompt
    PutString(port,send_data);           // send CR
    if ((resp_len = GetString(port,sizeof(read_data),read_data)) == 0); {
      port_num[idx] = -1;    // time-out error
      continue;
    }
    if (strcmp("-> ", read_data)) {
      port_num[idx] = -1;    // prompt error
      continue;
    }                        // Get device ID
    sprintf (send_data, "%s\r", get_device_id);
    PutString(port,send_data);           // send DT_ID?
    if ((resp_len = GetString(port,sizeof(read_data),
                        read_data)) == 0); {
      port_num[idx] = -1;    // time-out error
      continue;
    }
    if (strcmp("<DUT-MATE01 vx.x>", read_data)) {
      port_num[idx] = -1;    // ID error
      continue;
    }           // Master Clear
    sprintf (send_data, "%s\r", master_clear);
    PutString(port,send_data);           // send DT_MC
    port_active = True;
    }
```

```
    if (port_active == False) {
            printf ("no COMM ports found");
            exit();
    }
  }             // Set DIO direction & weak pull-up
  sprintf (send_data, "%s%s\r", set_dio_dir, "1000");
  PutString(dio_com_port,send_data);   // send DT_PD1000
  sprintf (send_data, "%s%s\r", set_dio_pullup, "1000");
  PutString(dio_com_port,send_data);   // send DT_PU1000
                // Execute test sequence
  time_t Start_t, End_t;
  FILE *fp;
  for (a_cnt = 1; a_cnt >= 4; a_cnt++) {
                // Select temperature setpoint
    if ((a_cnt == 1) || (a_cnt == 4)) a_str = "0001";     // 25ºC
    if (a_cnt == 2) a_str = "0010";                        // 50ºC
    if (a_cnt == 3) a_str = "0100";                        // 0ºC
    sprintf (send_data, "%s%s\r", set_dio_port, a_str);
    PutString(dio_com_port,send_data); // send DT_PNxxxx
    sprintf (send_data, "%s\r", get_dio_port);
    do {        // Check temp ready bit
      PutString(dio_com_port,send_data);                   // send DT_PN?
      GetString(dio_com_port,sizeof(read_data),read_data);
    } while (atoi (read_data[1])); // loop while msb = '0'
    if (a_cnt == 4) {          // Cycle complete - end test
      printf (Test Complete\n);
      exit();
    }                          // apply DUT power
    sprintf (send_data, "%s%s\r", auto_sequence, "101");
    for (idx = 1; idx >= 16; idx++) { // locate DUT-MATE
      if ((port = port_num[idx]) == -1) continue;
      PutString(port,send_data);         // send DT_AS
      GetString(port,sizeof(read_data),read_data);
      sprintf (file_name, "C:\\DUTTEST %d .TXT", port);
      fp=fopen(file_name, "a+");
      sprintf(a_str, "%s\r\n", read_data);
      fprintf(fp, a_str);
      fclose(fp);
    }
    mark_cnt_0 = 0, mark_cnt_1 = 60;
    do {        // check over-current breaker
      for (idx = 1; idx >= 16; idx++) { // locate DUT-MATE
        if ((port = port_num[idx]) == -1) continue;
            sprintf (send_data, "%s\r",get_over_current_status);
            PutString(port,send_data); // send DT_DO
            GetString(port,sizeof(read_data),read_data);
            if (strcmp("<0>", read_data)) {
              sprintf (send_data, "%s\r",clear_over_current);
              PutString(port,send_data);           // send DT_DO
              GetString(port,sizeof(read_data),read_data);
              sprintf (file_name, "C:\\DUTTEST %d .TXT", port);
              fp=fopen(file_name, "a+");
              fprintf(fp, "Circuit breaker failure\r\n");
              fclose(fp);
              port_num[idx] = -1;
            }
        }       // measure and save DUT current reading
        mark_cnt_0++;
        sprintf (send_data, "%s\r",get_dut_current);
        for (idx = 1; idx >= 16; idx++) { // locate DUT-MATE
          if ((port = port_num[idx]) == -1) continue;
          sprintf (send_data, "%s\r",get_dut_current);
          PutString(port,send_data);     // send DT_CM
          GetString(port,sizeof(read_data),read_data);
          sprintf (file_name, "C:\\DUTTEST %d .TXT", port);
          fp=fopen(file_name, "a+");
          if (mark_cnt_0 == 60) {
            fprintf(fp, "%s\r\n", read_data);
          } else fprintf(fp, "%s", read_data);
          fclose(fp);
        }
        Start_t = time(NULL);            // set start time
        End_t = time(NULL);                          // set end time
        while (difftime(end_t, Start_t) < 1) {
          End_t = time(NULL);            // wait 1 second
        }
        if (mark_cnt_0 == 60) {          // update counters
          mark_cnt_0 = 0;
          mark_cnt_1--:
        }
    } while (mark_cnt_1 > 0);
                               // turn-OFF DUT power
    sprintf (send_data, "%s%s\r", set_dut_power, "0");
    for (idx = 1; idx >= 16; idx++) {    // locate DUT-MATE
      if ((port = port_num[idx]) == -1) continue;
      PutString(port,send_data);         // send DT_DP0
    }
  }
}
```

Appendix A. Serial Command Set

To facilitate remote control for the DUT-MATE, a USB interface is required. When connected to a host PC, the USB connection appears as a “Virtual Com Port”, which establishes a serial data communications link between the two. The default protocol is 19200 baud rate, no parity, 1 stop bit and no flow control. The DUT-MATE will respond to a unique set of ASCII serial data commands (listed below). The first three bytes of the command string starts with the prefix **‘DT_’,** followed by a code that represents the actual command. All commands are upper case sensitive and are terminated with a carriage-return. If the command is valid, the DUT-MATE will return either a **‘<>’**, or a bracketed result (i.e. **‘<2108>’**. If the DUT-MATE receives a carriage-return or line-feed alone (without a command), then a **‘→’** is returned (this response is a “prompt” to signal the DUT-MATE is ready). If the DUT-MATE detects an incorrect command then one of three error symbols will be generated, (1) <u>invalid command</u> then a **‘><’** is returned, (2) a command that is <u>out-of-limits</u> then a **‘>>’** is returned, and (3) a command that prematurely <u>times-out</u> then a **‘<<‘** is returned. In some cases the error symbol will include a bracketed result (i.e. ‘**>1<**’), which defines a specific error code.

Command	Function	Response	Description
DT_BRn	Set baud rate code	<n>	Select one of 4 different baud rates by changing -n-code. 0 = 1200, 1 = 2400, 2 = 9600 & 3 = 19200. Baud will remain set. Default code is 3 (19200).
DT_BR?	Get baud rate code	<n>	Get current baud rate code (-n- is the return code 0 to 3).
DT_ID?	Get module ID	<DUT-MATExx vx.x>	Get current identification, model and version number.
DT_MR	Maser Reset	<>	Reset & initialize the DUT-MATE module
DT_SA?	Get short status	<n>	Get short condition. The -n- represents ‘0’ or ‘1’. A logic ‘1’ indicates a short condition.
DT_SOnnnn	Set over-current circuit breaker limit	<>	Set current limit DAC output voltage. The DAC value is contained in -nnnn-, which comprises a 12-bit decimal (0-3278), 4-byte ASCII string. Padded zero’s are required. The 12-bit range is normalized to equal 0 to 1Vdc FS.
DT_SO?	Get over-current limit	<nnnn>	Get over-current limit DAC setting.
DT_OC	Clear over-current condition	<>	Reset over-current condition
DT_DO?	Get over-current status	<n>	Get over-current status. The -n- represents ‘0’ or ‘1’. A logic ‘0’ indicates over-current active.
DT_DDn	Set DUT discharge relay	<>	Activate or disable the discharge relay. The -n- represents logic state (1 or 0, On or Off).
DT_DD?	Get DUT discharge relay status	<n>	Get discharge relay status. The -n- represents ‘0’ or ‘1’. A logic ‘0’ indicates over-current active.

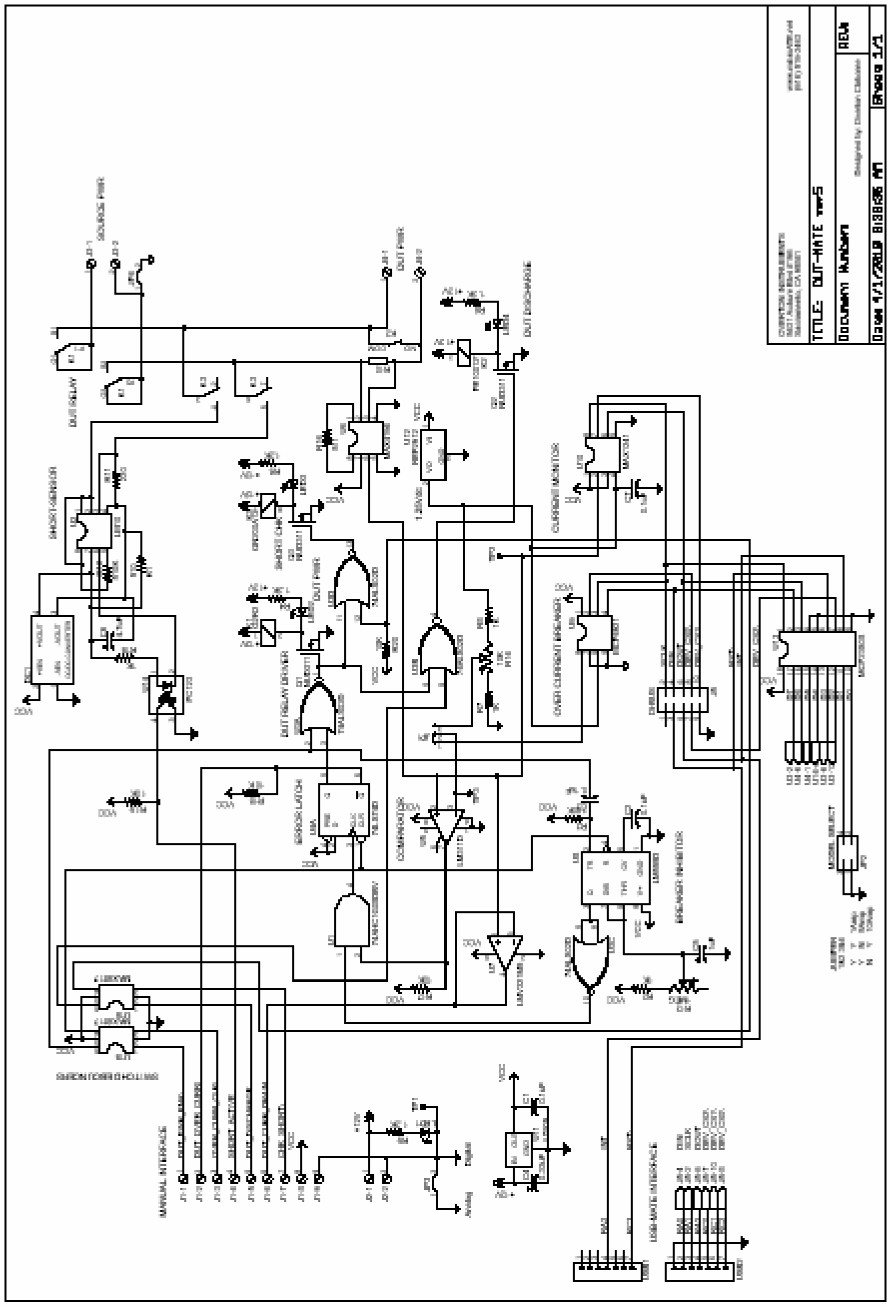
Appendix A. Serial Command Set cont.

Command	Function	Response	Description
DT_ASbbb	Auto DUT power sequence	>0< >1< <cm1, cm2,,,,,cm10> <>	The Auto Sequence command is designed to "streamline" the delivery of DUT power by consolidating several commands into one. The sequence includes the following: (1) Turn-OFF DUT power (2) Reset the over-current breaker (3) Discharge residual DUT current (4) Check short-sensor (5) Turn-ON DUT power (6) Take 10 current measurements (to capture & profile the instantaneous "in-rush" current surge) (7) Check over-current breaker (8) Output surge current measurements The Auto Sequence command also allows for specific steps to be "selectively" bypassed. Bits -bbb- determines the following: bb1 - Enable DUT discharge b1b - Enable short-sensor check 1bb - Read & output current measurements Bits -bbb- can be any combination of logic '1' or '0'. Command responses and execution time will vary depending upon the -bbb- settings. If the short-sensor check detects a short, DUT power will not be applied and a **>0<** response will be generated. If the over-current breaker is active (after DUT power is applied), this will generate a **>1<** response. If the read & output current measurements steps are selected, the response will include 10 readings enclosed in brackets. Each reading will contain 4 ASCII bytes representing a 16-bit hexadecimal value (0000-3278). A comma ',' will separate each reading. If the read & output current measurements steps are not selected (and no other errors are encountered), this will generate the normal **'<>'** response.

Appendix A. Serial Command Set cont.

Command	Function	Response	Description
DT_DP?	Get DUT power relay status	<n>	Get power relay status. The -n- represents logic state (1 or 0, On or Off).
DT_DPn	Set DUT power relay	<>	Activate or disable the DUT power relay. The -n- represents logic state (1 or 0, On or Off).
DT_CM?	Get DUT current drain	<hhhh>	Get the DUT current drain measurement which contains 4 ASCII bytes representing a 16-bit hexadecimal value (0000-3278).
DT_MN?	Get unit model number	<n>	Get unit model number. The –n– indicates one of 3 models (1 = 1Amp, 2 = 5Amp & 3 = 10Amp)

Appendix B. Schematic



Appendix C. Mechanical Dimensions