Using the Chinese Designed and Manufactured

DL24 Active DC Load

As a Low-Cost Substitute for a Professional Grade Active DC Load

Richard L. Grier, Copyright ©2021

**First let’s discuss the categories of users for this variety of electronics test equipment**. I can think of four types of users. I will leave it to your imagination to decide where I fit in the list.

1. Professional designer who is building a low-cost electronics bench that achieves the highest possible performance to cost ratio. This person may be an entry-level entrepreneur or a person building skills in an area peripheral to his or her primary activity. For example, a software engineer who needs to design and test purpose-built hardware to support software applications for data acquisition or control. There are many possible areas that correspond to this activity. Of course, there are many other areas that are “professional” (profit making) that might need to use low-cost test equipment.
2. A professional designer who has a generous assortment of high-quality and often expensive electronics test equipment who encounters the need to do occasional, non-demanding tests that can be done with at low-cost device. This user may hide a low-cost “non-professional” unit away from public observation and only bring it out when needed. Approbation avoidance.
3. The electronics hobbyist. Often the work product created by a hobbyist is as high quality as that produced by a professional, but the primary goal is the enjoyment of “making” and is not, primarily, driven by an attempt to make a profit.
4. A test engineer in a manufacturing environment. Here a goal may be to do product performance assurance and testing after final assembly. This engineer may be charged with creating a test fixture that does this validation. It may be possible that the engineers who designed the original product had very high quality and costly test equipment to do that part of the job, but having done a good job, all that is left is to make certain that the product delivered to customers meets the specifications that the original designer used. A manufacturing test system often does not need to test edge conditions, so it may be worthwhile to consider a low-cost solution.

**Second, let’s discuss the sort of things tests that are appropriate for the general DC Active Load tester.** This list used some information from other sources (included in the download in their original form).

A list of applications that might employ an active DC Load for electronics testing.

1. Power supply tests

* Steady-state load regulation. This is a measurement of how a supply reacts to a constant load. Load Regulation = (Vnl – Vfl)/ Vfl X 100 and is represented as %. Vfl, or Full Load Voltage, need not be unchanging, but the voltage is measured at specified current(s) where the load current is changed from zero to the maximum rated supply current. The rate of change for load current is low and is not intended to introduce abnormal power supply transient response. A power supply with good load regulation is able to provide an output voltage that does not change much with varying load current. The smaller the load regulation, the power supply is judged to be more stable and reliable. Typical well-regulated power supplies have load regulations of less than 1%, meaning that the output voltage will change by a maximum of 1% over the supply’s load current range. A well-regulated power ensures that the connected circuits operate correctly. Most switched mode power supplies have better regulation than linear power supplies.
* Transient response, also called Transient Load Response, to characterize the ability of the power supply to stabilize itself upon a step change in the load current. In order to verify the response, measurements of the rise and fall times upon a step change in the load is necessary. Generally, this type of test requires a load that is able to produce a rise and fall time approximately five times faster than the power supply.
* Current limit testing. Power supplies in constant voltage mode generally have a fixed or adjustable limit to the maximum current output. Current limit testing consists of measurements that show the behavior of a power supply and its current regulation. These measurements can be characterized by a voltage vs. current curve, which portrays how and when the power supply transitions from CV to CC mode.

1. Battery Testing.

* Battery Discharge Curves. When designing and testing batteries for powering a device, we should evaluate energy efficiency and lifetime. For this reason, a standard performance test consists of analyzing discharge curves that characterize the behavior of the battery. By observing these curves, the battery life can be measured, and its efficiency can be evaluated.
* A DC load can be an effective tool for measuring the internal resistance of a battery.

1. Solar Panel Testing.

A designer may need to determine the efficiency of a solar panel system. When connected to an inverter or battery charging system the goal is to convert maximum power from the PV panels. Maximum PV panel power depends on the panels themselves as well as environmental factors of temperature and solar irradiation.

We measure the maximum power from PV panels so that, despite environmental effects, they operate at their maximum power point (MPP).

You will notice that this list includes some  checkboxes. A “checked” box indicates that I think the DL24 Active Load is able to contribute in a useful way. Transient response testing cannot be done in any rigorous way with the DL24, though it is possible to do some simple transient tests – we’ll see later.

**Third, let’s examine the specifications for the DL24 Active Load.** I will start by reporting the manufacturer’s specifications and then I will add my own observations that confirm or contradict some of these. The published specifications are contradictory – the set in the “DT24 User Manual” that is furnished by the manufacturer (note it says, “DT24” while the actual unit is a “DL24” – I cannot try to interpret this discrepancy). The User Manual specifications are not worth reporting here. They do not accurately reflect the actual product. However, the specifications published on eBay (where I purchase my unit) seem to be fairly reliable. Here it is:Description

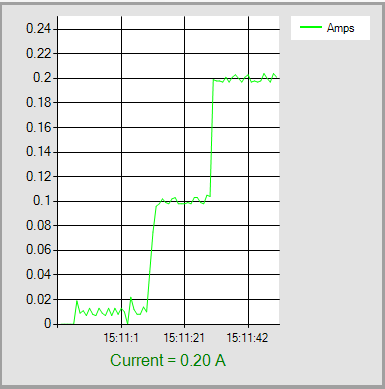
**DL24 150W Electronic Load Voltmeter Ammeter Battery Capacity Power Aging Discharge USB Tester  
  
Attention:**  
- Batteries are not included.  
- Exceeding the specified power, the product will be burnt out.  
- 150W/180W power means: according to the power calculation formula P = UI (power = voltage x current).  
- When inputting 10V, discharge current is about 18A. When inputting 20V, discharge current is about 9A. When input 30V, about 6A discharge current.  
  
**Product Description:**  
This electronic load can measure the voltage, current, power, capacity, power and discharge time of various batteries (batteries are not included), DC power supplies, data lines, power banks, chargers, and AC/DC power adapters, internal resistance, load capacity and other properties. Its function is more than that of electronic load meter of hundreds of US dollars, and its volume is relatively smaller. It is more more flexible to use. Thanks to its lower price, it is very suitable for manufacturers to verify, intimate instruments for digital enthusiasts, engineers and other experiments.  
  
**Features:**  
- 2.4-inch HD large color screen blue digital transmission curve version high-power tube digital load meter.  
- Support discharge aging test, which can be used to test the voltage, current, power, capacity, electricity, temperature, discharge resistance, time-limited discharge settings, stop voltage setting and other parameters and operation of various power supplies such as USB chargers, mobile power banks, battery and battery capacity, power adapters, etc.  
- Support Bluetooth wireless connection and wired computer connection modes.  
- Support four kinds of online APP (support for Android, Apple, PC computer Bluetooth wireless online APP and data wired online APP)  
- Four discharge modes: constant current, constant power, constant resistance, constant voltage.  
- High-power and large-discharge tube discharge test is used internally, summarizing the principle and evolution of hundreds of large-scale instrumentation circuits, integrating all major advantages in one, and displaying a variety of parameters on the screen of discharge aging, convenient and fast test, and powerful function!  
- 150W high power; 200V wide voltage; 20A high current. Strong performance, can be used for various discharge and aging detection.  
- 4 Operating Modes: CC-constant current operation; CV-constant voltage operation; CW-constant power operation; CR-constant resistance operation.  
- Intelligent temperature control fan: high-power, long-life cooling fan.  
  
**Technical Parameters:**  
- Test voltage: 2~200V  
- Working current: 0.2~20A  
- Constant load adjustment rate: +/-3%+3 bytes  
- DL24 discharge power: voltage x current <150W

Note, the DL24 is powered by 12V via a standard barrel jack connector. The ground connection used at the power jack is common to the load input ground connectors. One might choose to power the DL24 using a common switched-mode “wall wart” supply. Unfortunately, these commonly available supplies connect ground to the AC power mains neutral. Thus, a substantial difference in ground potentials may exist.

Use only an isolated 12V supply (transformer based is cheapest; my junk bin had several) if the load is to be used to test any device that itself is not isolated from the AC power mains. Otherwise, either the DL24 or the DUT may be damaged.  
  
**Attention:**  
- Actual operable current is limited by the maximum power. Please follow the law of conservation of energy to adjust current.  
- Built-in over current, over temperature and over power safety protection functions. If the protection interface pops up, please pay attention to the parameter adjustment. To adjust to the maximum power discharge, you can first slowly adjust the preset value and smooth the adjustment in the open discharge, so as to achieve the adjustment to the maximum power discharge.

**Wow**, that’s a lot to digest and it may cause some effort to interpret. However, the important specifications are shown in orange. Input voltage should be limited to less than 200 Vdc. The minimum input voltage is 2 Vdc; this is confirmed by my testing – so it cannot be used to test a single-cell 1.2-1.5 V battery, but a single LiPo battery with that can supply 3.7-4.2 V can be tested. I have used it at voltages up to about 60 Vdc, but I expect that higher voltages will be suitable, though the PCB design does not lend itself to examining track spacing. So, I might be inclined to restrict input voltage to less than 100 Vdc.

However, the current specifications also are important. The 20A maximum is obvious (but the DL24 allows load current to be set as high as 30A), but the 200 mA lower limit is less clear. I’ve used it with what I consider to be reasonable performance with at load currents of less than 200 mA. The design limitation at work is that the gate control voltage for the FET pass element that forms the actual “load” is difficult to match to the exact gate voltage needed to set the current. There is a current sense circuit that measures the load current and the ADC resolution of the microcontroller that adjusts the gate voltage is limited such are one bit (plus or minus) introduces what must be called “hunting,” where the load current varies around the set point in a significant way. For practical applications, this form of error may not be very important. Here is a screen shot from the PC application that forms the heart of my “improved” way to employ the DL24.

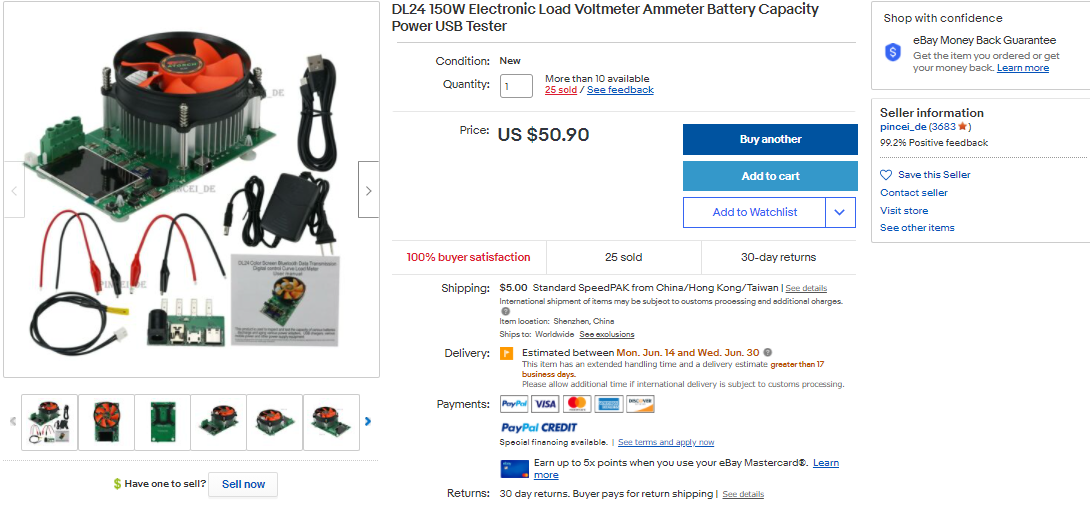


Low load current “hunting” error – Set currents of 10 mA, 100 mA and 200 mA

The current readings viewed using a multimeter between the voltage source and the DL24 load confirms this operation. Indeed, the load current varies measurably at, approximately, 1 second intervals. This is not a significant issue if the test is to measure battery discharge, where short-interval jitter will not introduce any serious error in discharge measurements. More commonly load current measurements will be at levels higher than 200 mA, where the limited resolution of the DL24 built-in microcontroller ADC introduces lesser load variations.

One of the obvious questions that one might ask is what does, - Constant load adjustment rate: +/-3%+3 bytes mean? As far as I can see it means that words are cheap. That is, while it may have meant something to the DL24 designer, it means nothing to us.

This is similar to the eBay listing for the unit that I purchased.



$56 for a complete DC load. But, the real selling point (and what makes this version more attractive than some slightly less expensive versions) is that it provides a USB serial a**nd** both SSP and low energy Bluetooth serial interfaces. The manufacturer provides a link that you can use to download both an Android smartphone app (Bluetooth LE) and a Windows 10 PC application that can employ either the USB serial or Bluetooth SSP serial ports.

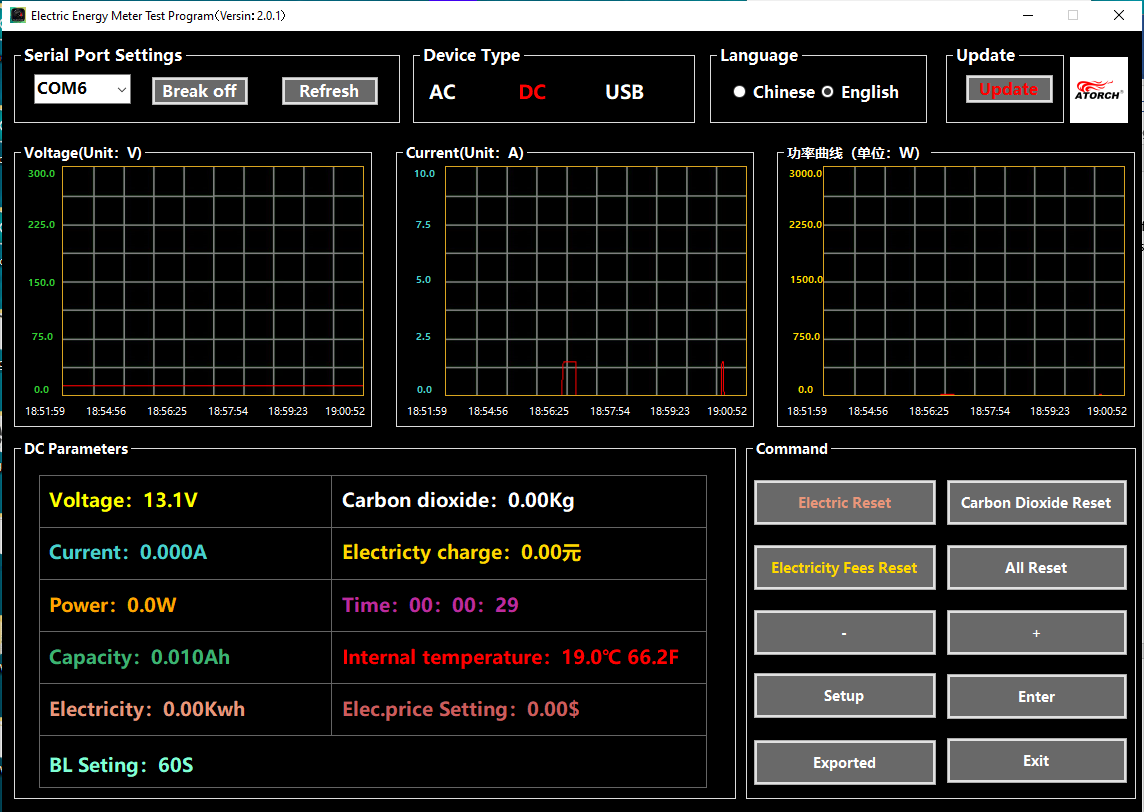
Sadly, the applications that you download are marginally better than nothing. They duplicate some of the functionality of the built-in LCD screen and some of the manual switch control functions. So, you can use these for very basic data viewing (though the UI defaults on startup to Chinese and when switched to English retains a few Chinese alphabetic elements). In addition, only the basic Constant Current (CC) function is available in the applications. Other functions, Constant Voltage (CV), Constant Resistance (CR), and Constant Power (CP) cannot be accessed. We will soon discover why.

**There is a very important function that these applications do not provide.** The main reason to use a PC or smartphone application is to log data. If a projected test executes for an extended time a user cannot be expected to open Notepad or Excel to record results. I want the application to archive this data to the computer file system for subsequent use.

**Fourth, I wanted to design a PC application that does every job that I can assign as potentially useful and to provide that application to others**. What follows is a description of the process.

The initial step is to determine how the application that the manufacturer provides controls the DL24 and how it interprets data sent from the DL24. The manufacturer does not document this serial communications protocol, so it was up to me to “reverse engineer” it. In the process I hoped to understand any limitations that might exist in it. I expected a number of limitations and I was not disappointed. The serial protocol is as basic as it could be made to allow it to do simple things and nothing more.

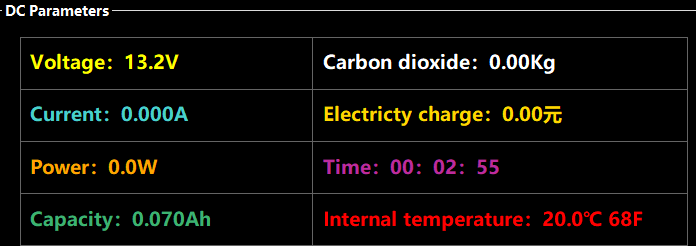
The actual reverse engineering process took some effort, but I was able to work out most critical details. I used an inline software serial monitor (Advanced Serial Port Monitor from aggsoftware.com, but there are others available that also will work) to capture the message traffic between the manufacturer’s PC application and the DL24. I exercised each button on the UI to see what command packet was sent to the DL24 and captured all data packets (messages) from the DL24 to analyze the protocol. Here are the notes I took in this process. All screen grabs in this section show the manufacturer’s PC application.



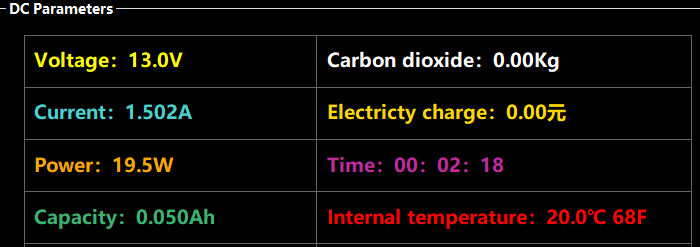
The serial speed is 9600 bps.

Sent from the device.

FF 55 01 02 00 00 84 00 00 00 00 00 07 00 00 00 00 00 00 00 00 00 00 00 00 13 00 00 02 33 3C 00 00 00 00 56



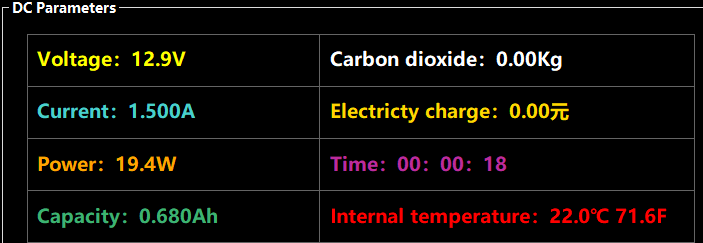
FF 55 01 02 00 00 83 00 05 DB 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 13 00 00 01 32 3C 00 00 00 00 A8



The current reading seems to be the 9th and 10th 8 bit fields. 05DB = 1499d, but this is close enough to 1502d that the difference in time between captures causes this difference.

The voltage reading seems to be the 6th and 7th 8 bit field. 84 = 132d, 83 = 131d MSB only.

FF 55 01 02 00 00 81 00 05 DA 00 00 35 00 00 00 00 00 00 00 00 00 00 00 00 17 00 00 15 1E 3C 00 00 00 00 5A



Here we see the 3RD-4th field 00 81 = 129d. This consistent with 12.9V (fixed point, 1 decimal). Thus, 02 47 = 55.90 V.

The serial protocol seems to support only 4 significant digits, though the unit’s LCD display shows 6 significant digits. Is this a problem? I’d say not really. The extra 2 digits are lower than the built-in microcontroller’s ADC resolution, thus are provided to make it look “pretty”.

Current is scaled by 1000 and voltage is scaled by 10.

So, this leaves temperature. The unit has an internal sensor, which displays temperature near the MOSFET. But, the board also offers an external temperature sensor. The internal temperature seems to be represented by the 26th 8 bit field (MSB only). 13 = 19d and 17 = 23d, which is “close” to the displayed values of temperature. The PC application does not appear to support the external temperature sensor. More study needed, if temperature sensing is to be added.

FF 55 01 02 00 00 81 00 05 D9 00 00 81 00 00 00 01 00 00 00 00 00 00 00 00 16 00 00 33 2F 3C 00 00 00 00 DC

The blue field in bit position 28-30 is hh mm ss time stamp. The timestamp incremented each time a packet is sent from the board (once per second), when the board mode has been selected to be “run” by either sending the start/stop command or my manually pressing the Start/Stop pushbutton on the board. This timestamp resets when the board is initially powered up **and** when the Reset command is sent from the PC. The count does not reset to zero when the board mode is changed to Stop, so a subsequent Start will resume at the previous time.

The highlighted orange fields may be associated with the external temperature sensor. The scaling is difficult to interpret because the actual room temperature is about 17 degrees C (x11). However, these two bytes (three if the C3 contributes) showed a significant difference when the external temperature sensor was connected. Still more to think about, if this feature is to be understood.

The field 3C may be measured AC frequency? (no AC input, so this is a WAG)

What about commands from the PC application?

Reset: FF 55 11 02 05 00 00 00 00 5C

Setup: FF 55 11 02 31 00 00 00 00 00 repeated presses cycle through digits of current set point

Plus: FF 55 11 02 33 00 00 00 00 02 increment selected current digit

Minus: FF 55 11 02 34 00 00 00 00 03 decrement selected current digit

Enter: FF 55 11 02 32 00 00 00 00 01 toggles start/stop

Electric Reset, Electric Fees Reset, and Carbon Dioxide Reset: FF 55 11 02 01 00 00 00 50

Brown byte in the 13th byte is yet to be identified.

Settings are not retained when power to board is cycled.

Checksum is calculated by summing the Xor of the present byte with the checksum of previous bytes(??)

After a reset message is sent from the PC, the first receive packet is:

FF 55 02 01 01 00 00 40 FF 55 01 02 00 00 82 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 14 00 00 00 00 3C 00 00 00 00 91 - Note, that 02 01 01 seems to be an acknowledgement (the equivalent field in a “normal” packet is 01 02 00). The board also zeros the count when reset, and this packet acknowledges this action. There may be more meaning hidden in this field.

FF 55 02 01 01 00 00 40 is the acknowledgement packet sent when all commands are issued. This does not appear to contain any board or measurement state information.

The charts do not auto-scale on the Y-axis. This makes them harder to read for inputs at the lower operation ranges.

The Bluetooth adapter supports SSP connections. To use it wirelessly with your BT equipped PC, open:

Settings (Gear icon)

Bluetooth & other devices

Bluetooth (Mice, keyboards, pens, or audio and other kinds of devices)

Make certain the DL24 is powered up

Select DL24-SSP (not BLE) and enter the passcode 1234

**Fifth, I need to determine what can and cannot be done using this protocol.**

1. I **can** duplicate the function of the DL24 On/Off (Start/Stop) tactile switch button. The Enter button on the provided application sends a command to the DL24 to perform that operation.
2. I **can** duplicate the function of both the “+” and “-“ DL24 tactile switch buttons. The corresponding application buttons send commands for these operations.
3. I **can** duplicate only one function of the DL24 Setup tactile switch button. The Setup button on the provided application sends a command to the DL24 to execute a short press of that button. However, the DL24 Setup tactile switch button also permits a “long-press” to change board from the default CC mode to CV, CR or CP modes. The “long-press” function is not supported by the serial protocol (and is not present in the application provided by the manufacturer, for obvious reasons).
4. The board power on default operation is Constant Current mode, with the digit select cursor placed in the first digit to the right of the decimal point. The DL24 allows the user to select other digit positions by single press of the “Setup” button. The serial protocol follows this convention. The DL24 does not retain this selection through power cycling. The serial protocol does not include and field data to indicate the current cursor position, so the use must cycle power to the DL24 before sending commands from the PC application.
5. The manufacturer’s application includes “Electric Reset”, “Carbon Dioxide Reset”, and “Electricity Fees Reset” buttons, but each of these send the identical command that is sent when “All Reset” is pressed. This command resets the timestamp that is included in the data packet from the DL24. This timestamp reset is useful and I incorporate it in the application that I have developed.
6. The manufacturer’s application displays Current (A), Voltage (V) and Power (W) both digitally and as strip-charts. I provide this very useful set of information. The manufacturer’s application also displays internal temperature, which I didn’t find interesting enough to include.
7. The manufacturer’s application provides a button marked “Exported” and if this does something, I cannot find it. I presume this is a logging function that might be done later. Logging is vital for many engineering or test applications. I include logging.
8. The manufacture’s application does not attempt to automate any DL24 board operations. I have provided automatic test functions, limited by the restrictions of the serial protocol and overall board design.
9. The DL24 Active Load sends data packets at 1-second intervals as described above. The protocol is fixed-length binary. I will assume that field numbering from 0, although the notes above count from 1. Zero base numbering is use to index binary arrays in the application, so I will document the fields using the zeroth ordinal in the field description. Each bit is shown in hexadecimal.

* Header: FF 55 – 1 bytes fixed format, bytes 0-1
* Packet type: 01 02 00 or 02 01 01 – 3 bytes, data or ACK respectively, bytes 2-4
* Empty: 00 – 1 byte, byte 5

Data packet fields:

* Voltage: XX XX – 2 bytes, range 00 00 (0.00V) to C8 00 (200.00V), bytes 6-7 note1
* Current: YY YY – 2 bytes, range 00 00 (0.0A) to 1E 00 (30.00A), bytes 8-9 note1
* Empty: 00 00 – 2 bytes, bytes 10-11
* Unknown: UU – 1 byte, byte 12
* Empty: 00 00 00 – 3 bytes, bytes 13-15
* Unknown: UU – 1 byte, byte 16
* Empty: 00 00 00 00 00 00 00 00 00, bytes 17-24
* Internal Temperature?: TT - 1 byte, byte 25
* Empty: 00 – 1 byte, byte 26
* Timestamp: HH MM SS, 3 – bytes, bytes 27-29
* Unknown: UU – 1 byte, byte 30
* Empty: 00 00 00 00 – 4 bytes, bytes 31-34
* Checksum: CS – 1 byte, byte 35

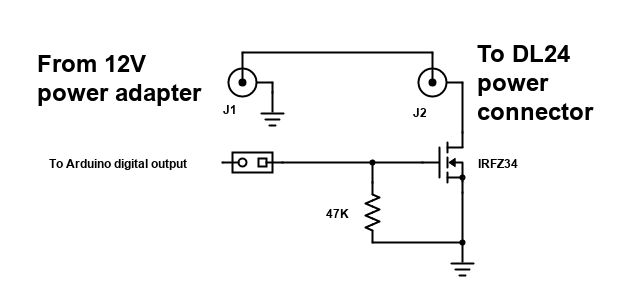
Note1. I have inferred these limits from the specifications.

**A Professional PC application design.**

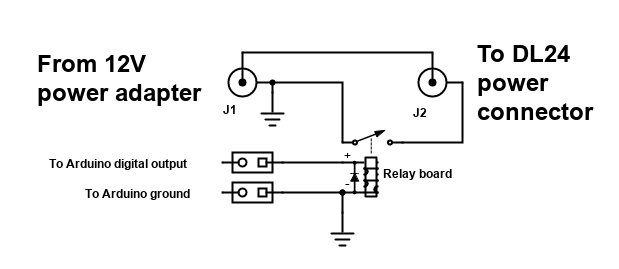
Let me assure the reader that by “Professional” I mean that it meets the needs of most non-professionals and some of the needs of a pro. It also adds some automated testing methods, data logging and a mechanism to assure that the PC application and the DL24 are “synchronized” so the user has minimal responsibility to verify that the desired test conditions are present on both. To accomplish these modest goals,

* The PC application uses only three field values that are sent from the DL24: Voltage, Current and Timestamp. Other data fields are ignored.
* I’ve added data logging with files created in Comma Separated Value (CSV) format.
* I’ve added code that automatically searches for a DL24 that is connected to the PC, either by USB serial or wirelessly by Bluetooth SSP. The user does not have to know which serial port is being used.
* I’ve included both manual operation (similar to that of the manufacturer’s software, but with some small additional capability) and a set of automatic tests that I label “Automatic Test Profiles.” Included in the automatic tests are “Load Regulation” which is a quick test for power supply voltage regulation testing; “MPP” which is a test that automatically adjusts the load current from minimum and increases it in steps until the maximum power is delivered to the DL24 – this is intended to be used with a solar array to validate array specifications (the user must determine appropriate solar illumination needed for this test); and “User Profile” to allow the user to create a simple script that cycles the DL24 through various load conditions with timing determined by the script – this is table-driven and requires no programming.
* There is a Configuration dialog that allows the user to set limits for both manual and automatic tests and to add appropriate notes and modifications to the log files that are generated when logging has been selected.
* I’ve designed an optional Arduino based microcontroller board that the PC application can use to cycle power to the DL24. When the DL24 board is repowered, the default conditions can be inferred. This software automatically detects the USB serial port used by the Arduino and if that controller is not located, the software continues assuming that the use has manually powered the DL24 and that it is in its default state.

Connect your Arduino to a power control circuit similar to one of the following. Connect the male jack from the 12V supply for the DL24 to the female plug (J1) and connect the male jack (J2) to the DL24. How did I select these components? I found them in my junk supplies for the FET version and I had a relay board left over from another project for the relay version. Both of these function well.



FET version power controller



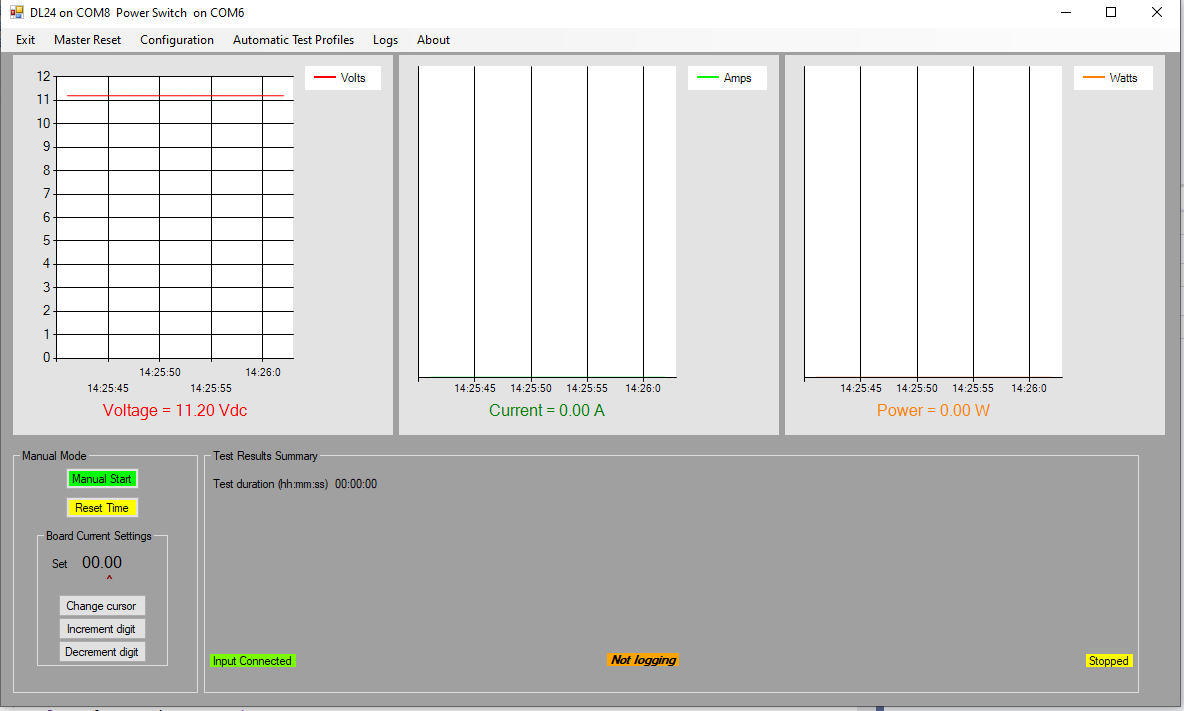
Relay version power controller

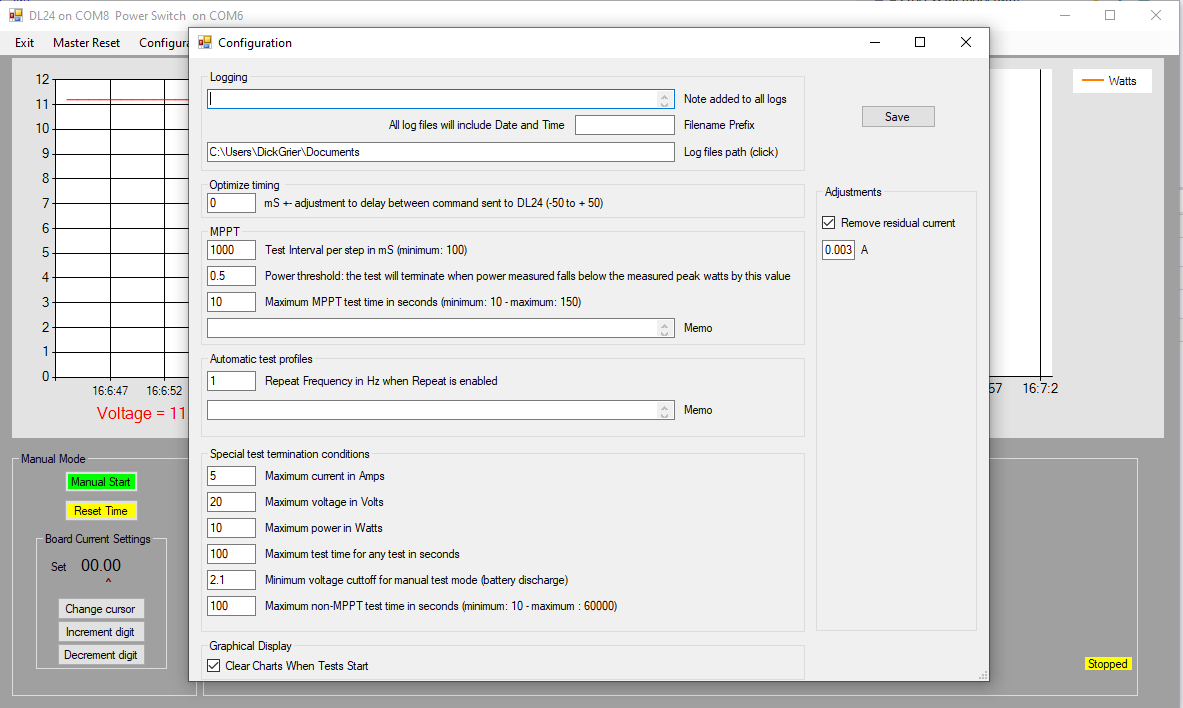
I omitted the ground connection from the Arduino to the FET control circuitry. The Arduino ground must be connected to the power controller ground.

The relay version is a simplification. The relay board control input is connected to the Arduino digital output. 5V, ground, and digital output are connected from the Arduino to the relay board.

The Arduino sketch is included in the download.

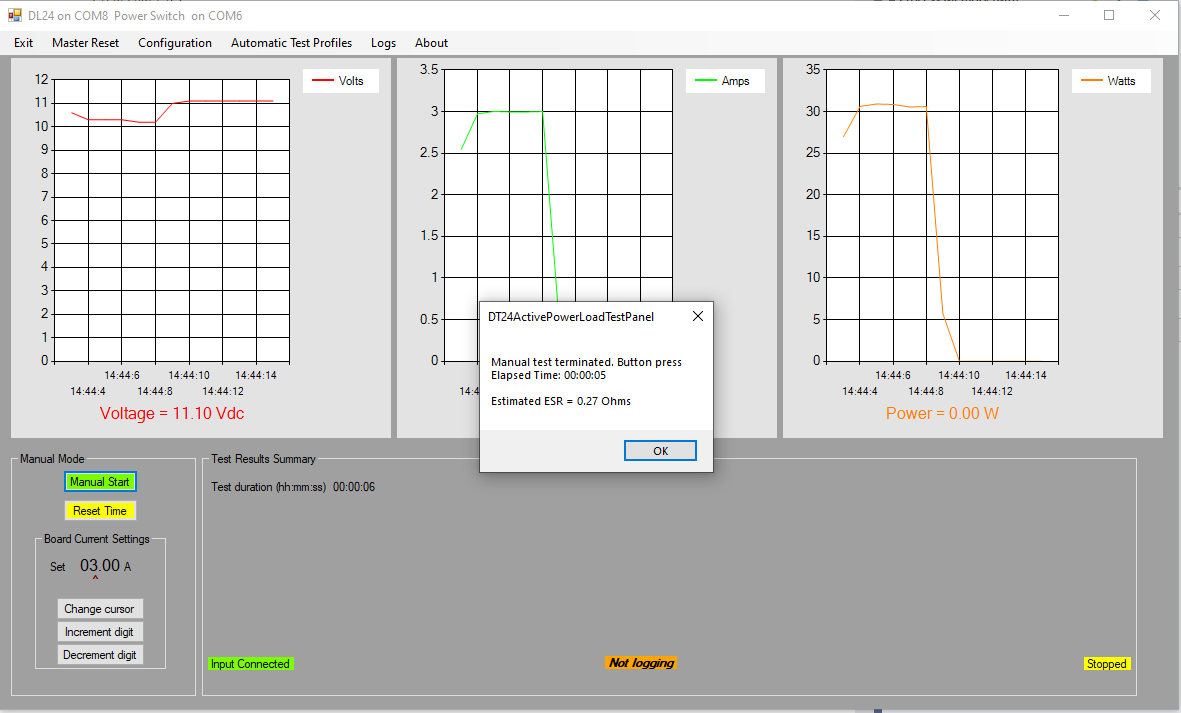
**The “Heart” of the project. A proper PC application**.

Typical panel UI at startup

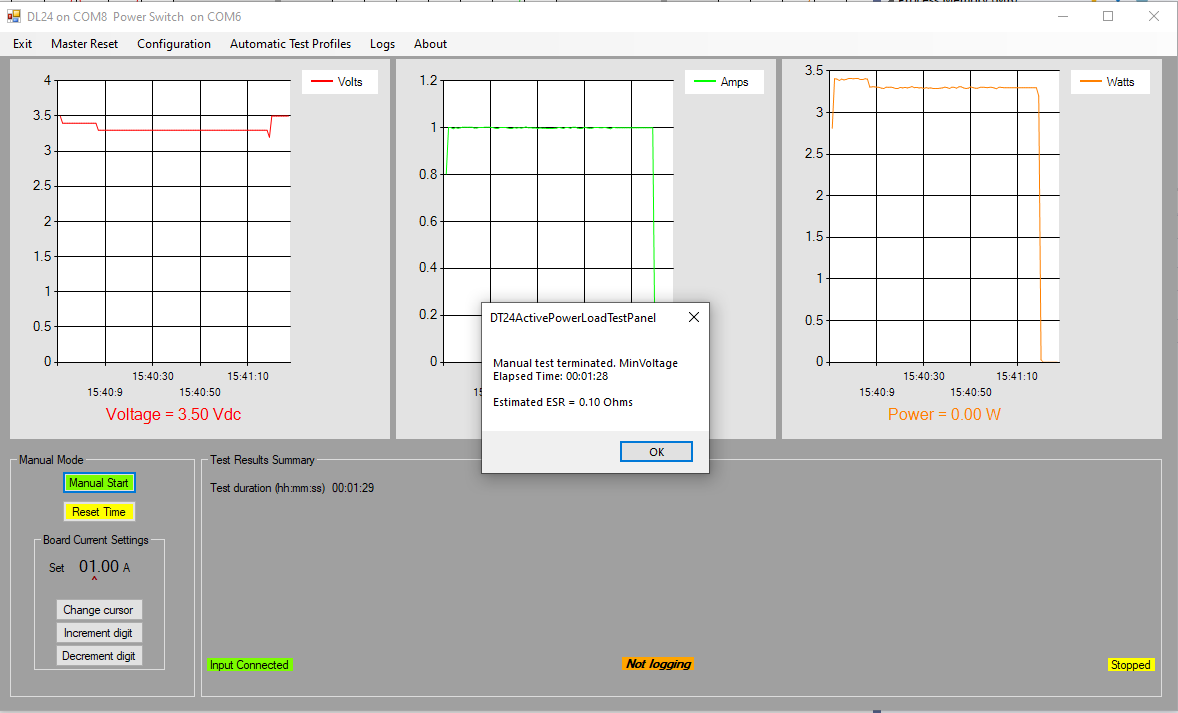


Typical Configuration UI

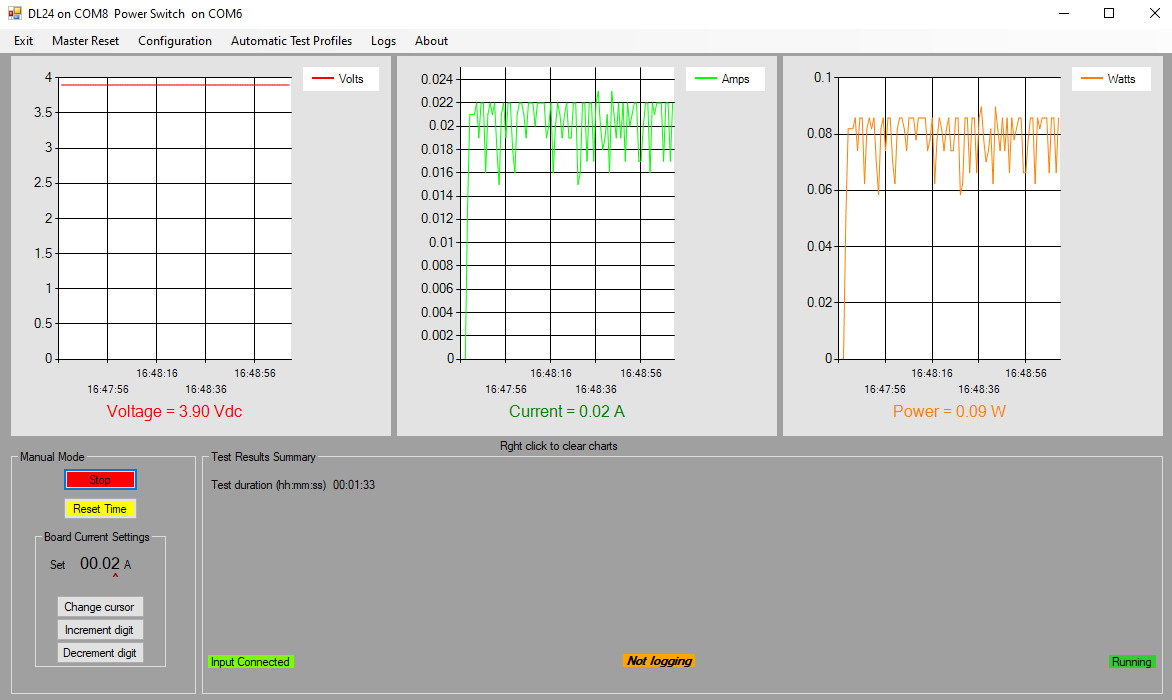
Typical Manual Operation, load current = 2.1 A



Typical termination of manual test (Short duration ESR test)



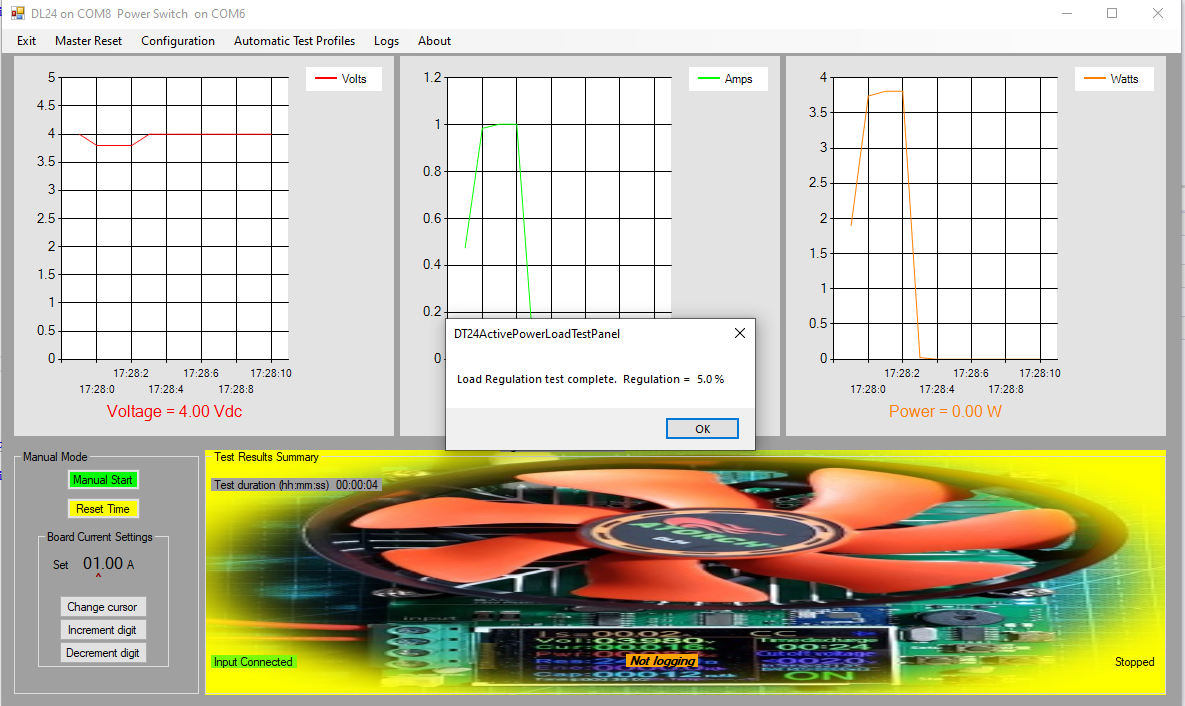
Typical termination manual test (partially charged LiPo battery)



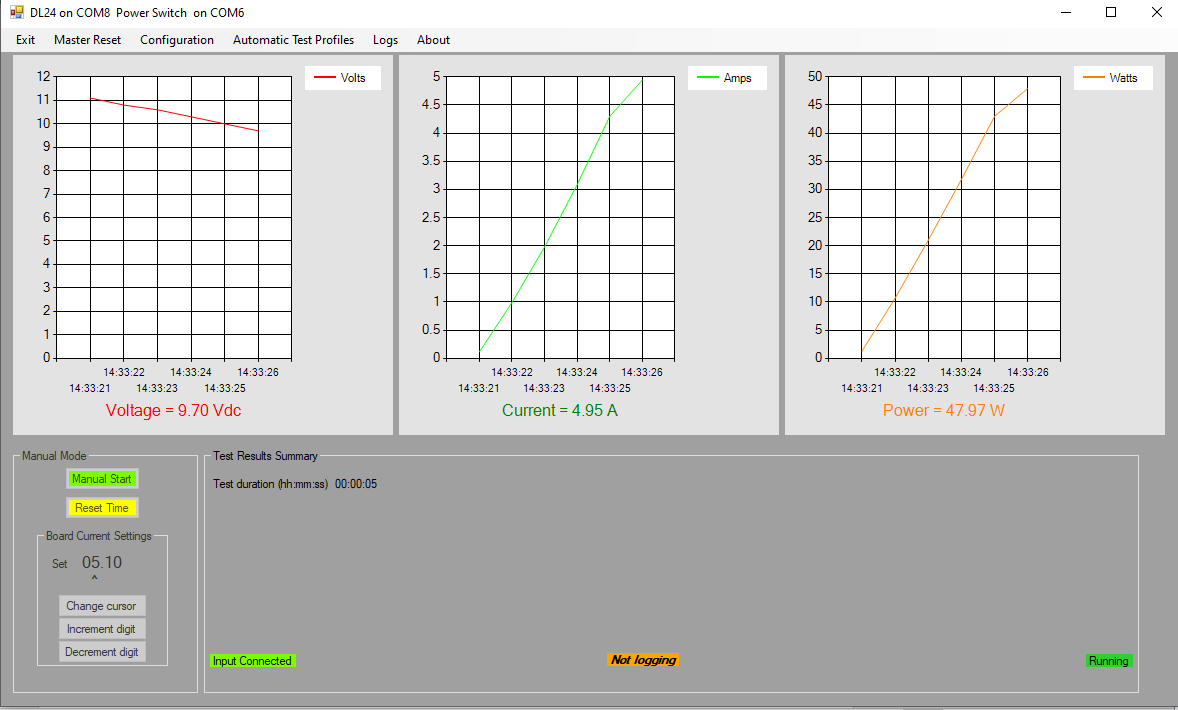
Typical “hunting” at low set current settings

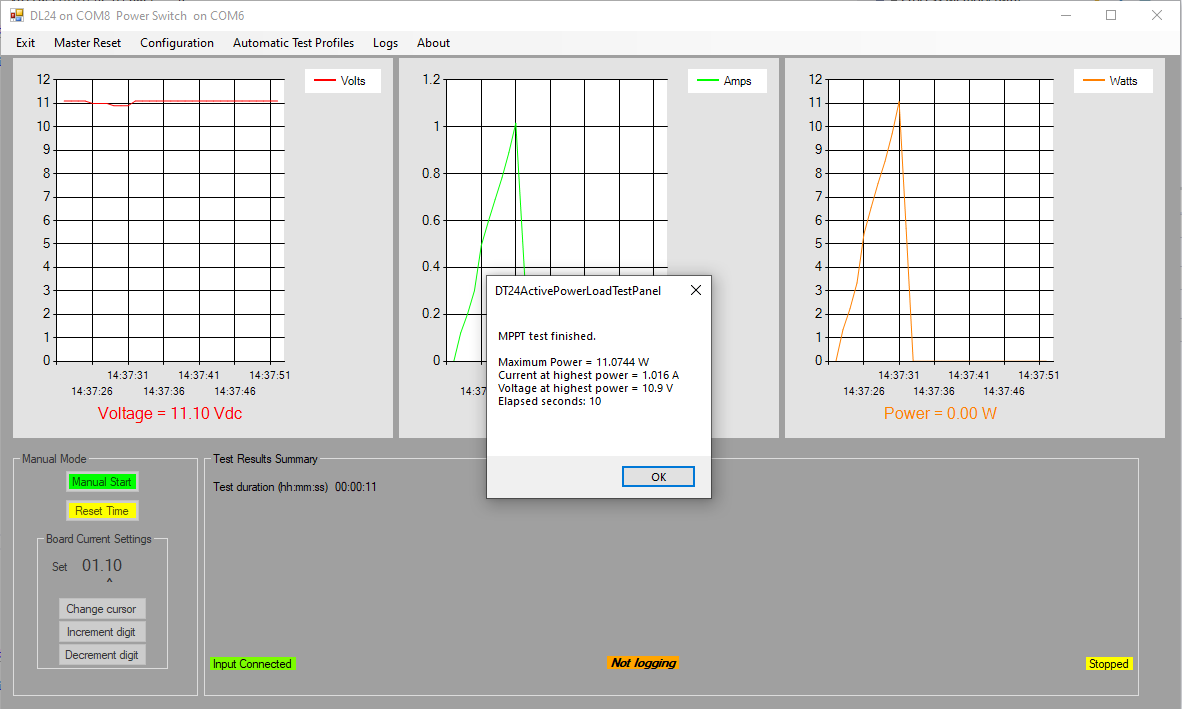


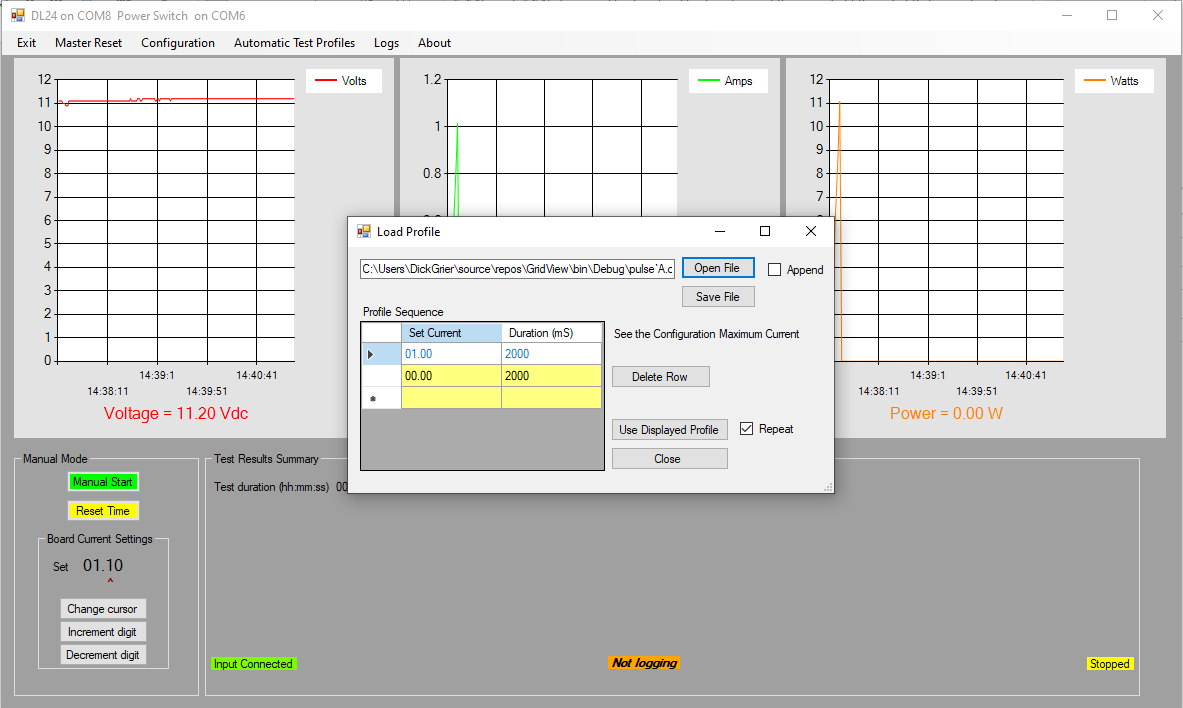
Automatic Test Profiles menu

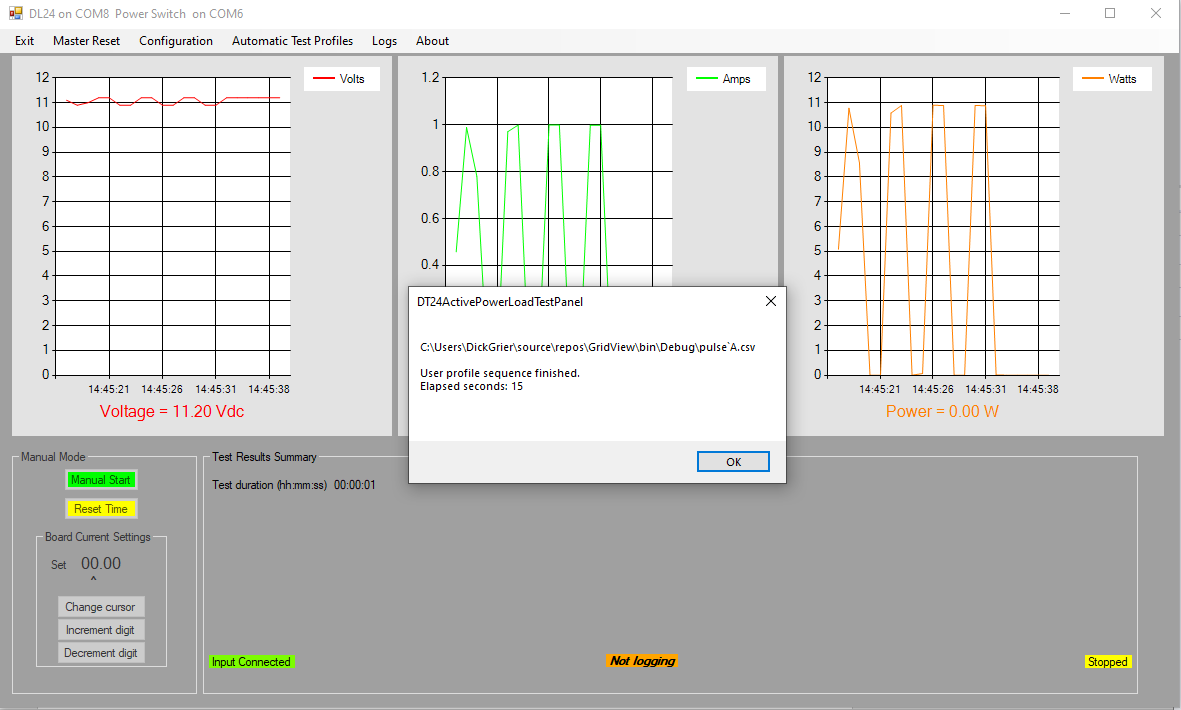


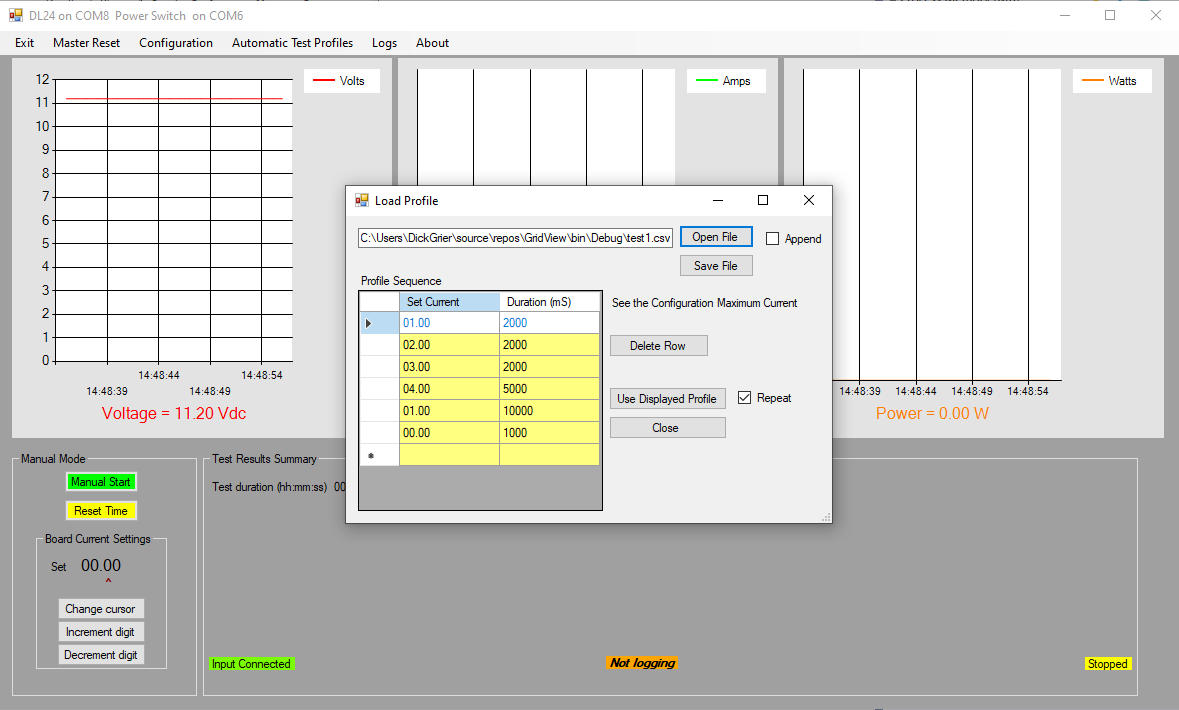
Typical Load Regulation test

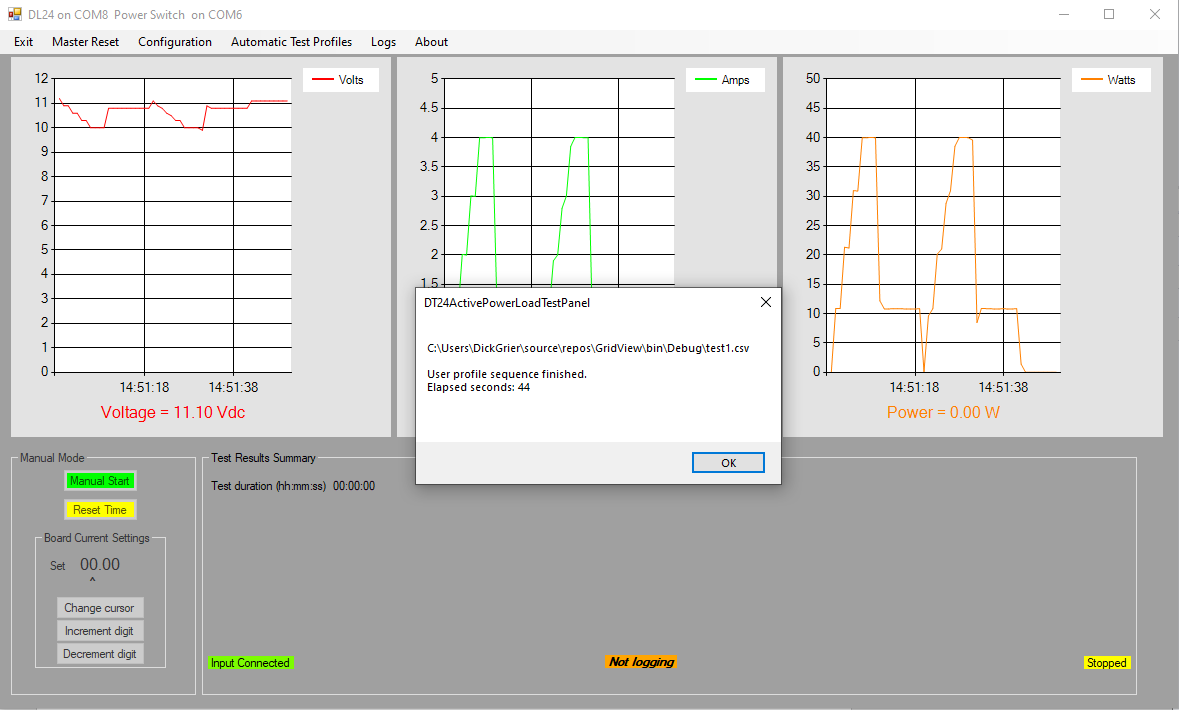
Typical MPP test startup

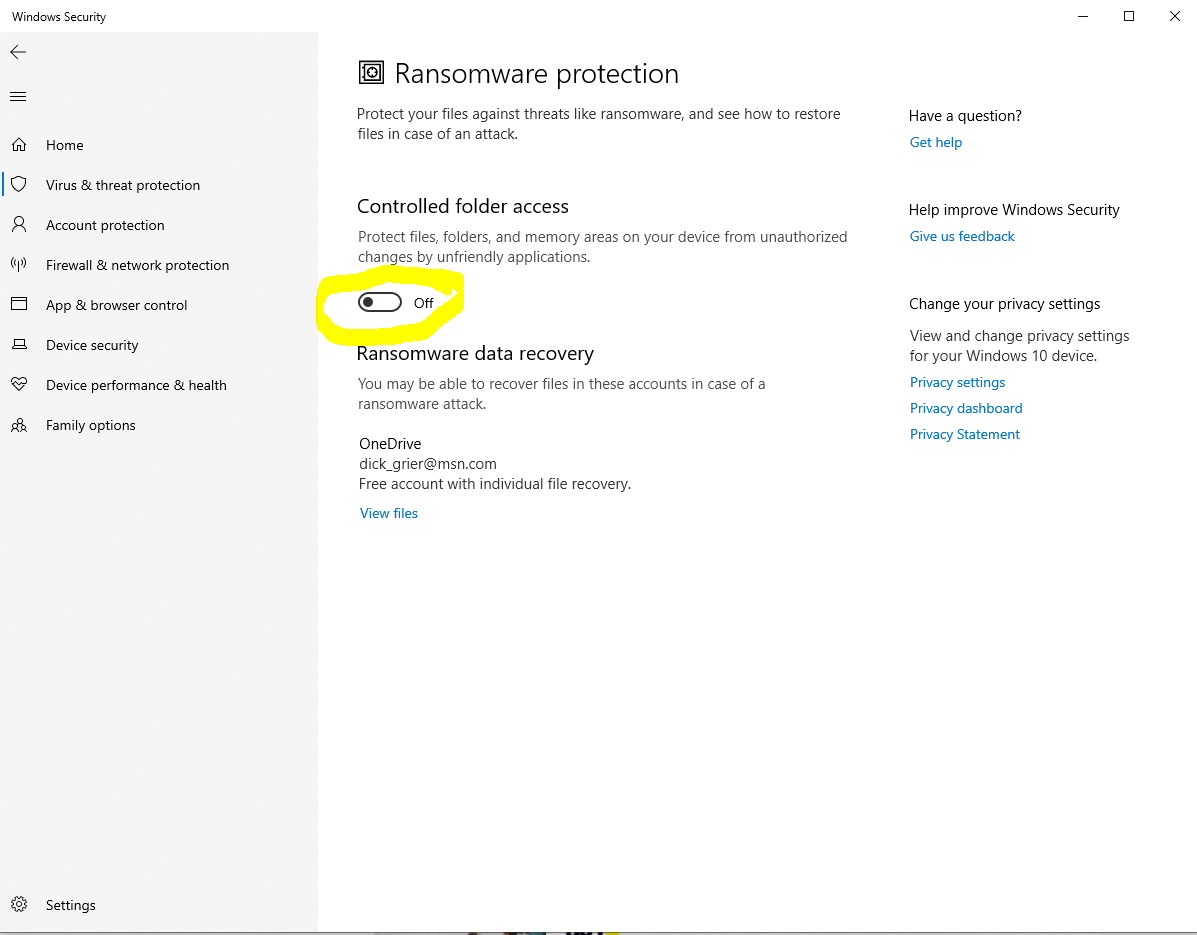
Typical MPP termination

Typical selection start UI for a User Profile – in this instance a 0-1 A “pulse” repeated load

Typical “transient response” to this form of test with four load pulses

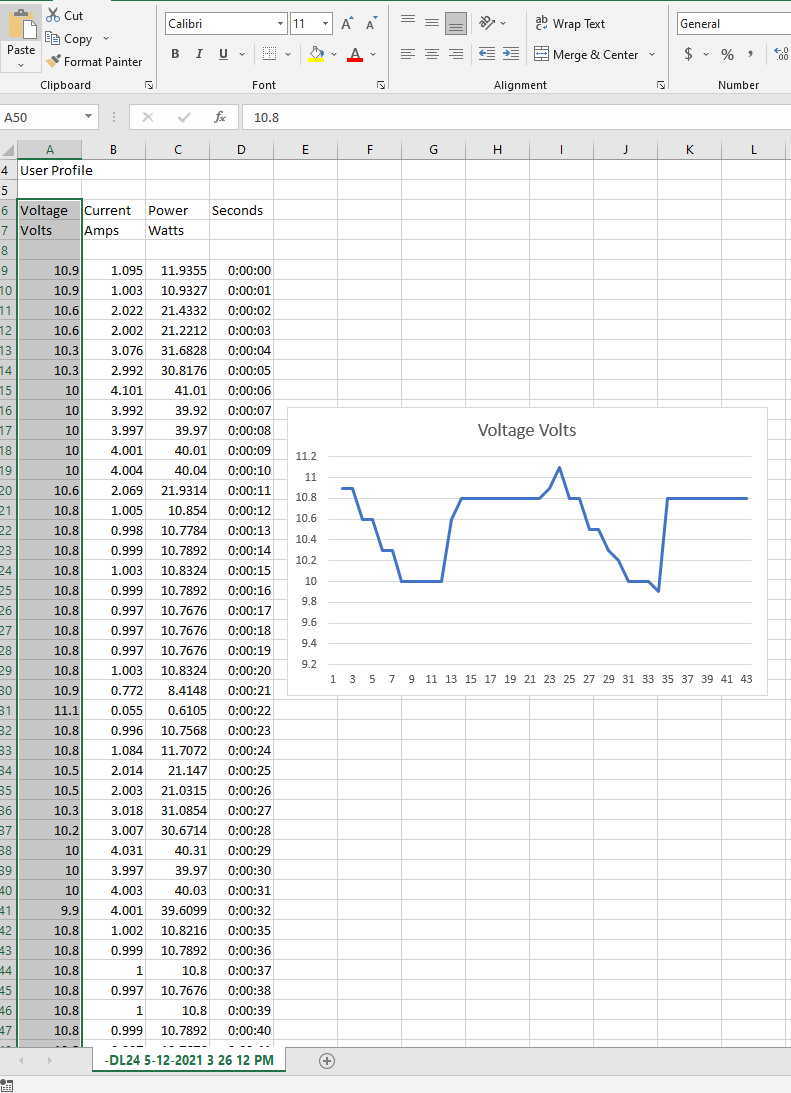
Typical User Profile with a variable set of load levels

Typical “transient response” to this form of variable load test

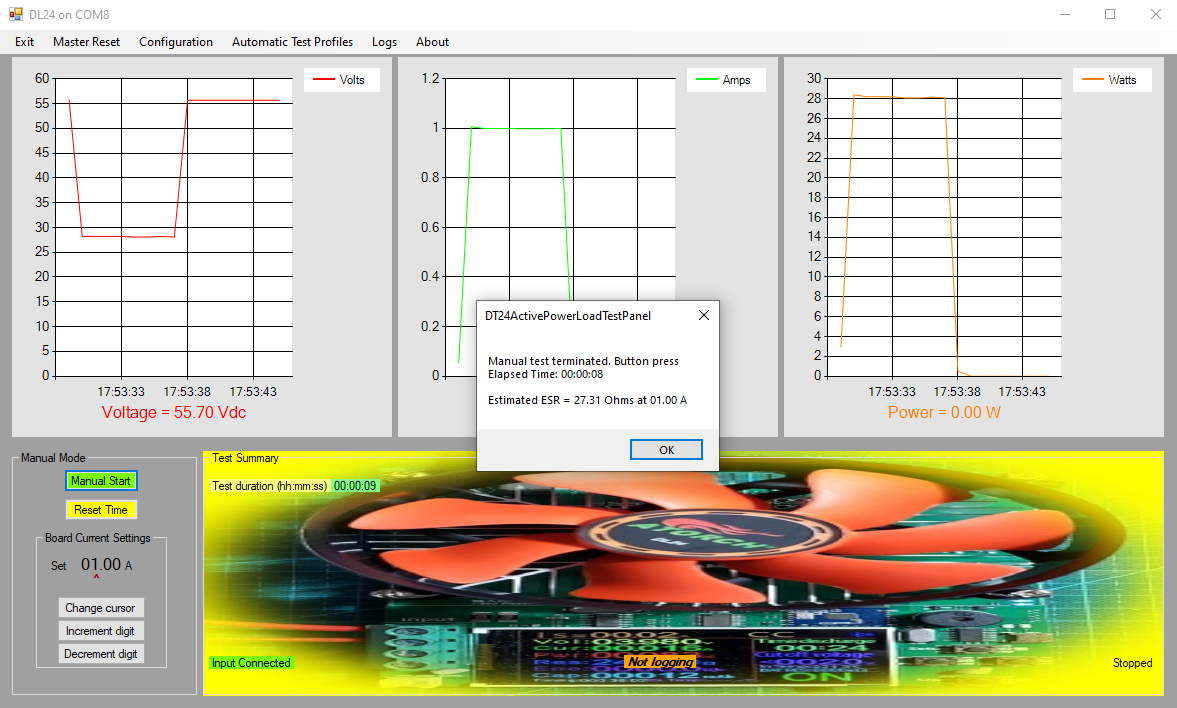


You may need to do this to enable logging to a specific folder (like Documents)

These screen captures take you through the most common tasks that might be encountered. Note, some of the screens show the most recent UI, with the garish image of the DL24, but the underlying details are accurate.



Log viewed in Excel with a chart for the Voltage column inserted



The highest DC voltage that I have used – also shows startup without the optional power switch

Here is some additional information.

Right-click on the charts to reset them without changing other conditions.

All parameters that may be configured are persisted so that the next time the program executes these parameters are restored.

The estimated ESR may be helpful when testing a battery, but it is just simple single-point test. Actual battery ESR follows a complex curve that depends upon load current and varies significantly over the entire battery discharge cycle.

The DL24 and this application, together, form a sampled-data acquisition system with a sample rate of 1 Hz (the rate that the DL24 sends data packets). This rate cannot be increased. Thus, any operational change made while acquiring data will be limited by the sample rate. Only the most basic transient load tests should be attempted – all the while recognizing this basic limitation.

The application was written in VB.NET using Visual Studio 2019 Community Edition. Source code is included on the CDROM download that I provide with my book*, Visual Basic Programmer's Guide to Serial Communications 5* an Amazon.com Kindle eBook (ASIN: B00NF0MRTO). If your copy of the CDROM is not up-to-date, you can request a new download link. Just provide proof of purchase.

Comments and suggestions are welcome.