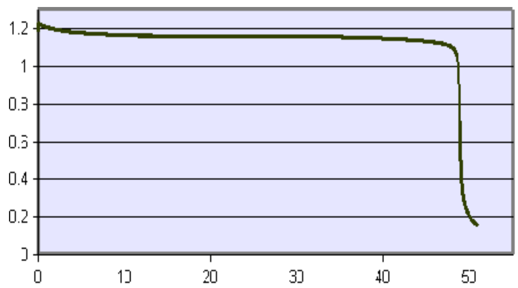
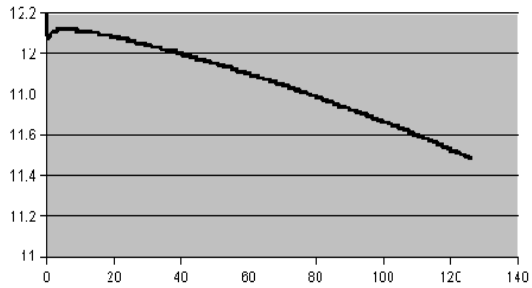
Battery Capacity Characterisation Analyser & Software

Measured discharge characteristic of a 1.2v, 800mAh AA NiCd battery



Measured discharge characteristic of a 12v, 7Ah Lead Acid battery



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Introduction

This project is to enable the discharge curves and Capacity of various batteries to be measured.

A battery under test is discharged through a load, which will vary depending on the type of battery being analysed. The voltage of the battery and current delivered through the load are monitored by a computer until the battery voltage falls to the minimum discharge level. The software will then display the capacity of the battery. The unit is controlled via the Parallel port of a PC using Visual Basic 6.

The main components of the circuit are:

Power Supply
This converts the 240V AC mains input to +12V, -12V and +5v.

MAX187 12bit Serial A to D Converter and MAX DG508A Multiplexer
Takes inputs from the Voltage Amplifier (Load Current) and Voltage Reducer (Battery Voltage) circuit via the Multiplexer.

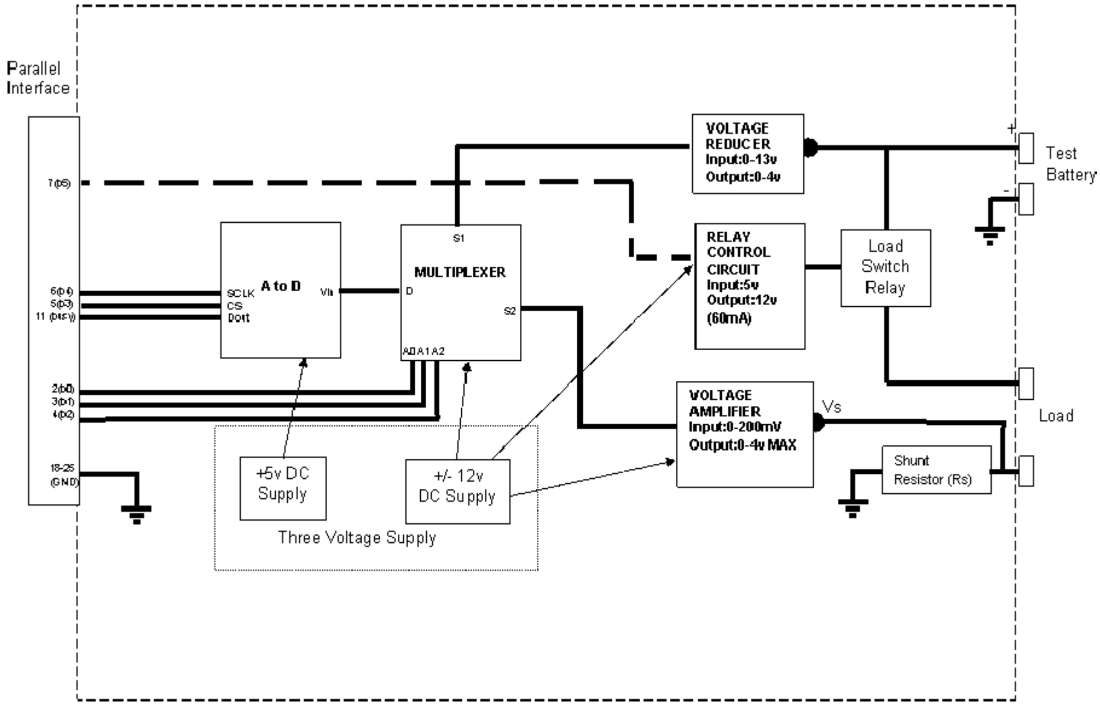
Relay Control Circuit
Switches the Load on or off using a 12V relay.

Voltage Amplifier
Amplifies the Shunt voltage measured across a 0.1ohm resistor in series with the load to bring it within the range of the A to D converter

Voltage Reducer Circuit
Reduces the battery voltage to bring it within the range of the A to D converter

Load
A range of loads will be used depending on the battery type under test.

Basic Circuit Block Diagram

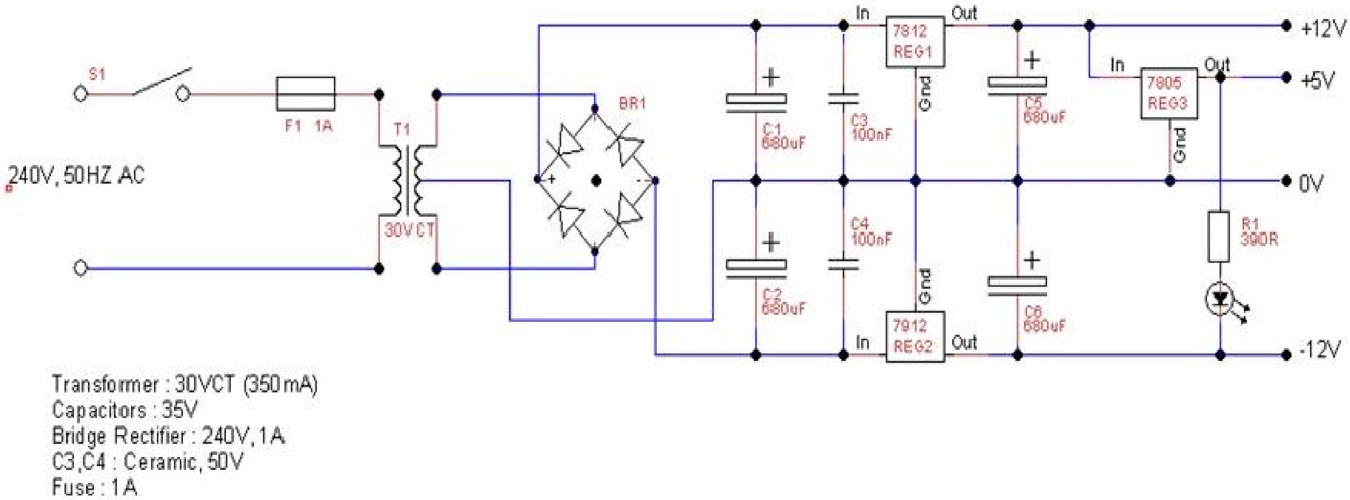


Three Voltage Power Supply

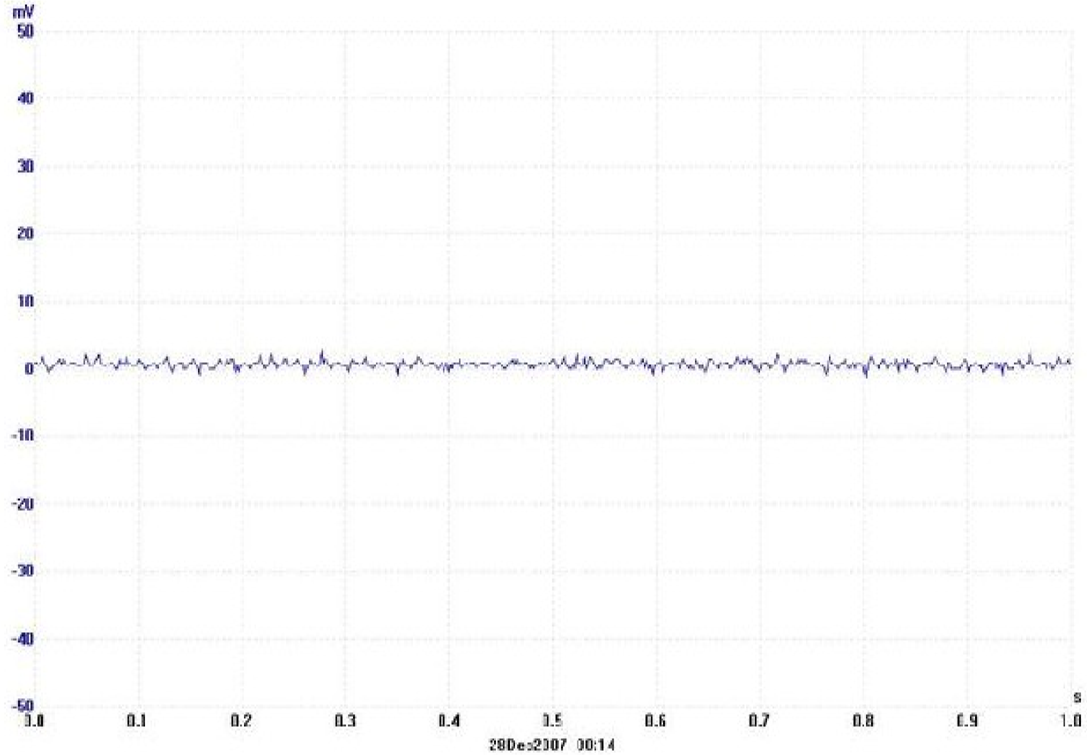
This circuit provides a +/- 12V and a +5V supply.

+12V: Relay Coil
Voltage Amplifier (741 op-amp)
Multiplexer (MAX DG508A)

-12V: Voltage Amplifier (741 op-amp)
Multiplexer (MAX DG508A)
+5V: AtoD converter (MAX187)



+12V Supply ripple under full load with relay coil energised



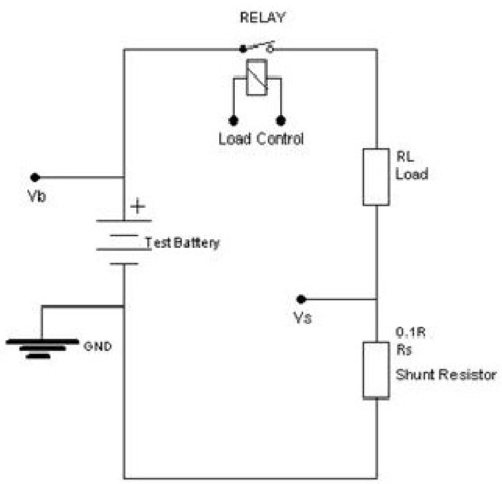
Load Control Circuit

This circuit consists of the following:

Test Battery
For the circuit shown below, this would typically be any Lead Acid battery with a rating of >1Ah. With different loads, it will be possible to test other batteries.

Load (RL).
This is provided by a load box providing a number of different loads depending on the battery being tested.

Shunt Resistor (Rs)
This enables the circuit current to be measured. This is a Bare Element Resistor, chosen for its excellent Temperature Coefficient. The circuit current is equal to : I = Vs / Rs. In practice I will measure the circuit current using a DMM at different levels and convert the measured voltage into a current reading using software.



Relay
The switching of this relay will be computer controlled; therefore the computer can remove the load when the battery voltage drops below a certain value.

Vb= Battery Voltage.
Vs = Shunt Voltage (Proportional to Circuit Current)

The Load is controlled via the Relay.

EG. 12v, Test Battery
6R Load

Nominal Circuit Current I = Vb/(RL+Rs)
I= 12/6.1 = 2A (24W)

The voltage developed across Rs should be : V = I * R
V = 2 * 0.1 = 0.2V (200mV)

The computer closes the relay to start the discharge cycle. In practise we won't allow the battery to discharge below a certain value.

Test set-up of circuit diagram

The DMM was used to measure Shunt Voltage (Vs).
With a 12V (1.3Ah) battery the Shunt voltage was 0.160V.

The load current measured with the DMM was 1.500A.
We can now calculate the value of the Shunt Resistor.

Rs = Vs / I
Rs= 0.160 / 1.5 = 0.107ohms.

The nominal value of the resistor is 0.1ohms.

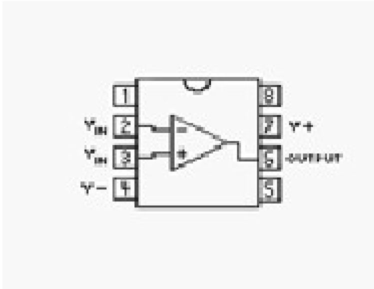
In reality the correlation between Vs and the load current should be checked at different current and voltage levels, as it will vary due to the temperature co-efficient of the shunt resistor (20ppm/°C)

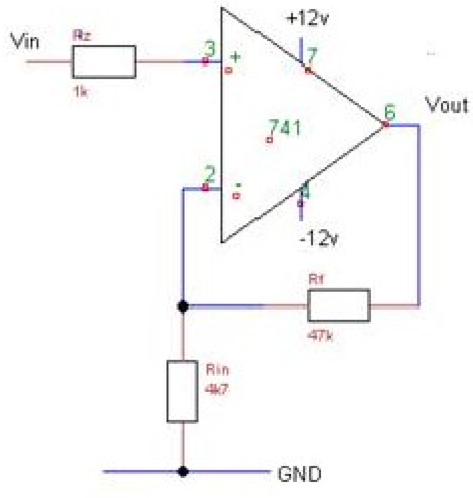
In practice, I measured the value of Rs (as above) at up to 12V, 2A load and found its value to change by no more than 10%.

I

Voltage Amplifier

The voltage measured across the shunt resistor will vary from approximately 0v to 200mV depending on the load used. The MAX187 AtoD has an input voltage range of 0 to 4v. The non-inverting amplifier below has a gain of 11, which will give a maximum output voltage of 200mV * 11 = 2.2v.





Calculation of Gain
Gain = (Rf+Rin)/Rin
Gain = (47000+4700)/4700 = 11

The amplifier was constructed on breadboard and tested as follow:

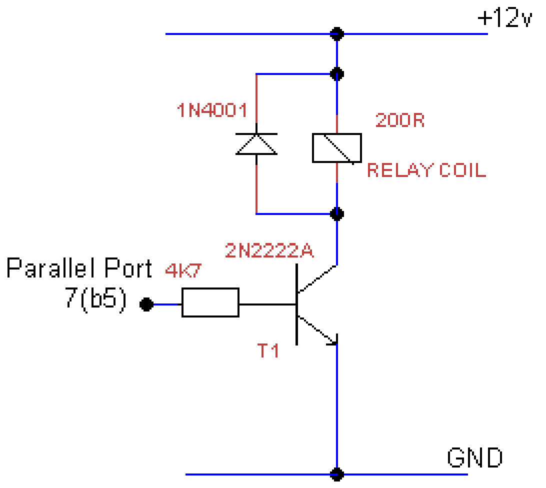
Input Voltage	Output Voltage	Gain
50.0mV	0.568V	11.4
123mV	1.362V	11

So, the measured gain of the 741 is approximately 11, as caclulated.

Relay Control Circuit (Load Switch)

The relay is triggered by the output of b5 of the parallel port. The relay coil requires 12v to energise. The resistance of the coil is 200ohms, therefore a current of 12v / 200ohms = 60mA will be drawn. The parallel port output of 5v at a maximum of 12mA isn't sufficient to energise the relay coil. The circuit below will allow the +5v signal from the parallel port to switch +12v.

The diode protects the transistor from back EMF which will be generated when the relay coil is switched off.

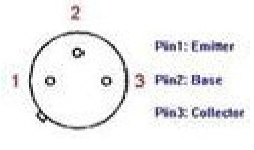


Relay Coil Load Current (Ic) = 12v/200R = 60mA

Load Current / Max parallel port current
= 60 / 12 = 5.
We need a transistor with an hfe >5. It's good practise to choose a transistor hfe of 5x this value i.e 25.

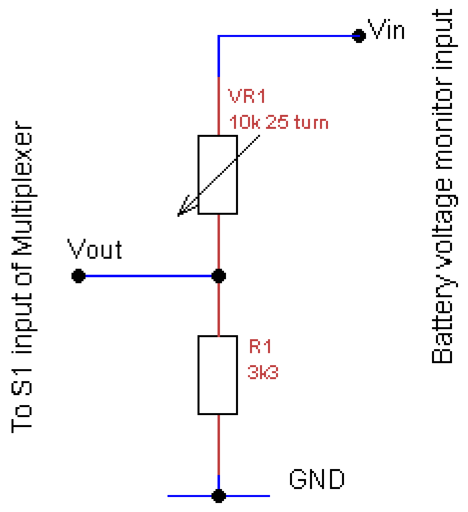
2N2222A chosen – hfe=100, IC(max)=800mA

Calculated value for base resistor:
Rb = (Vc . hfe) / (5 . Ic)
Rb = (12 . 100) / (5 . 0.060) = 4000
Rb = 4k7 chosen.



Voltage Reducer Circuit

The AtoD converter can only accept voltage inputs of up to +4v. As the max voltage of a battery could be >13.5V the voltage needs to be scaled down. A simple potential divider can be used to achieve this.

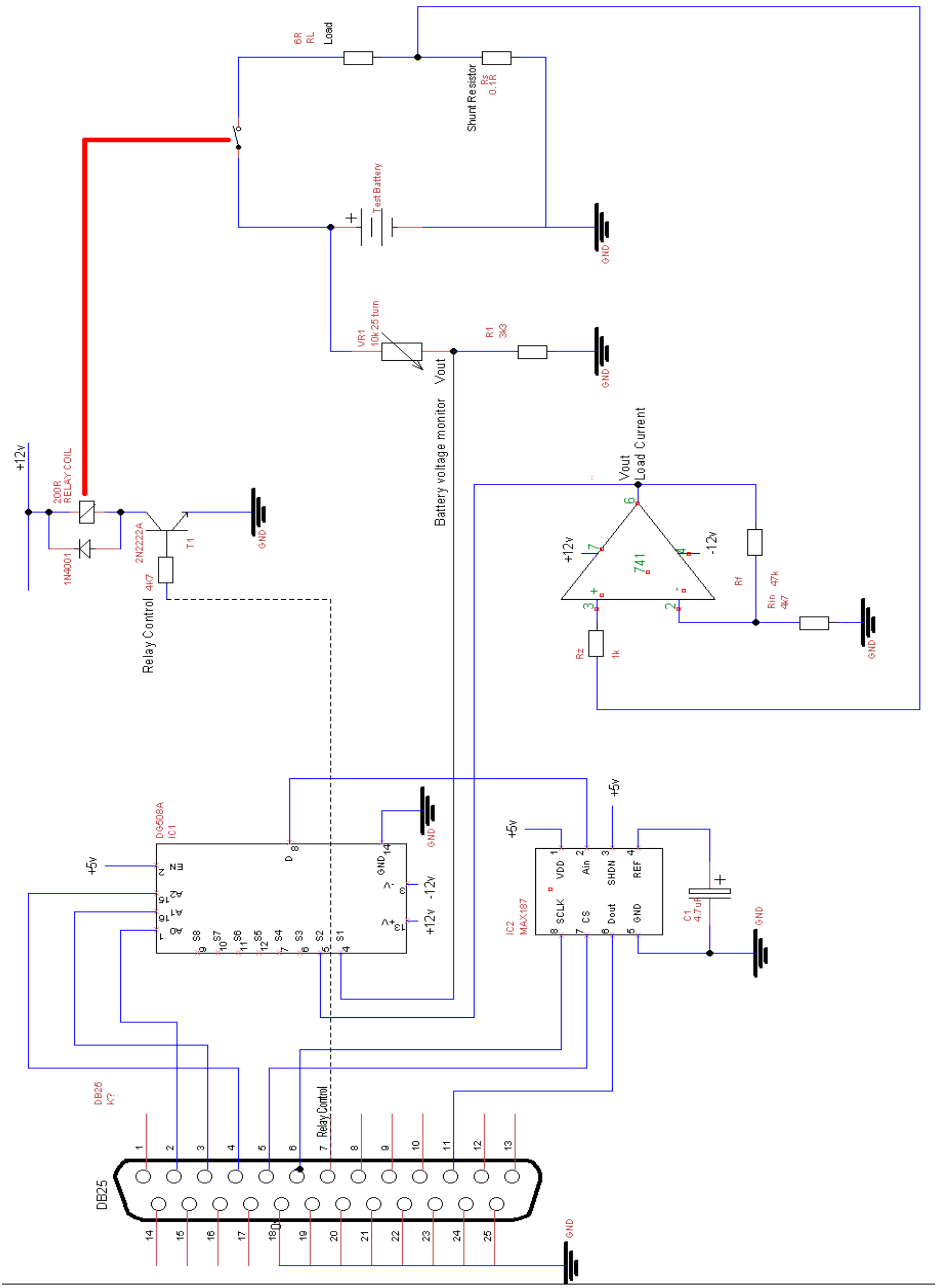


Vout = (R1 / (R1 + VR1)) . Vin.

Vin is measured from the positive terminal of the battery under test.

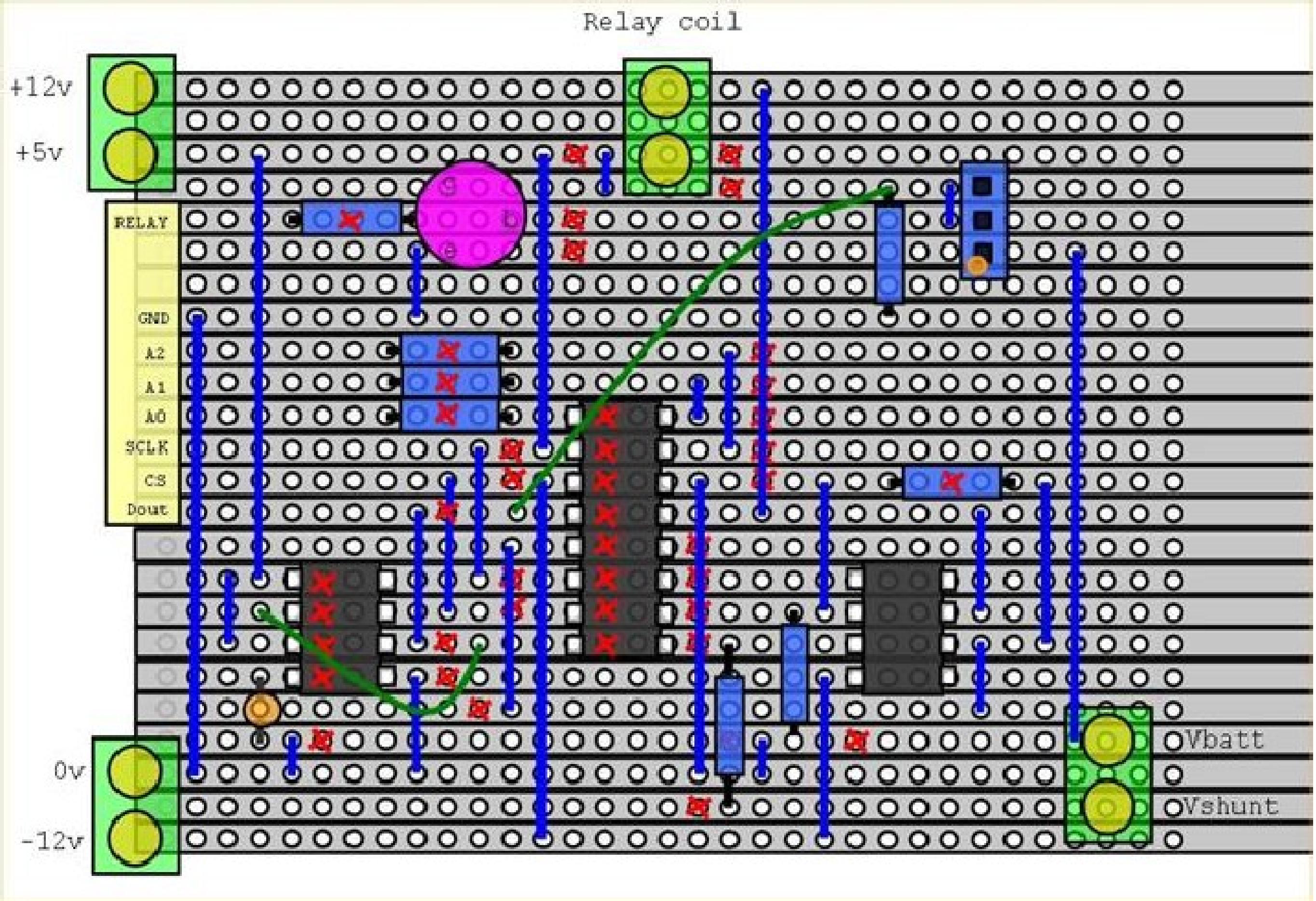
A test voltage of 13.5V was be inputted and VR1 adjusted to give make Vout 4v.

Complete Circuit Diagram, excluding PSU.

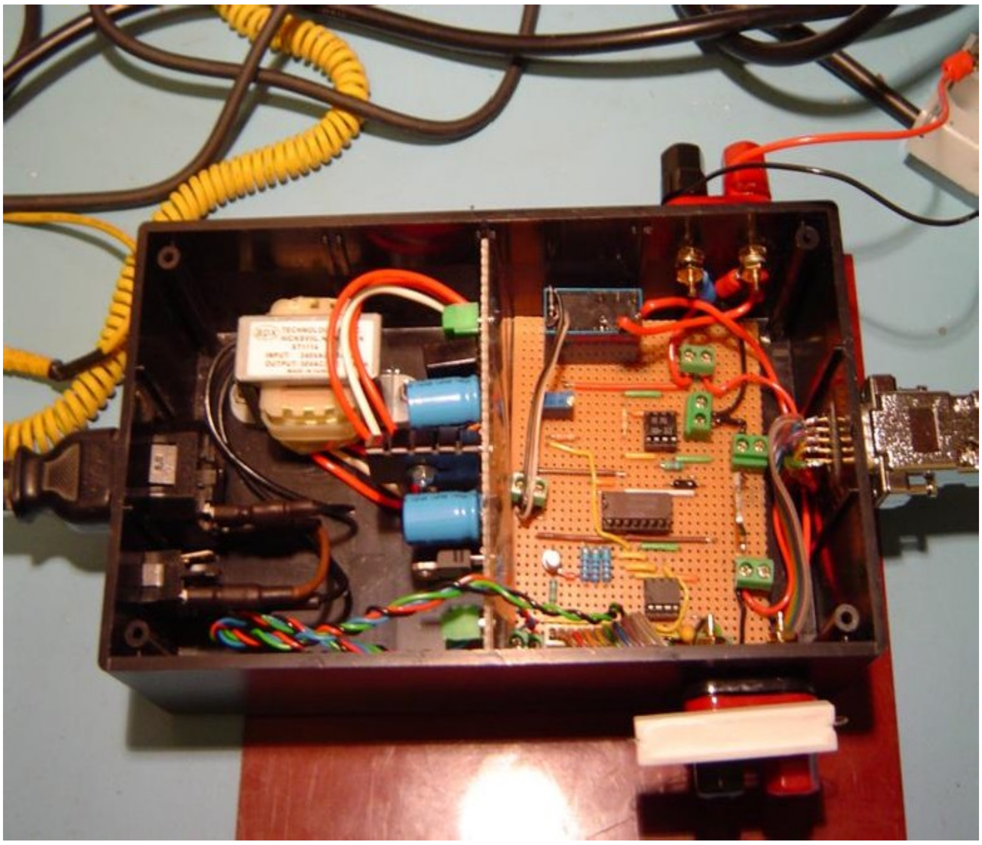


The Battery Voltage from the Voltage Reducer circuit and the Load Current from the Voltage Amplifier are connected to the S1 & S2 inputs of the multiplexer respectively. Address lines A0 to A3 on the multiplexer are used to select the desired input (S1 or S2). The multiplexer can take up to 8 inputs, but for this project I am only using two.

Stripboard Layout



Constructed unit showing PSU board and interface board mounted in box

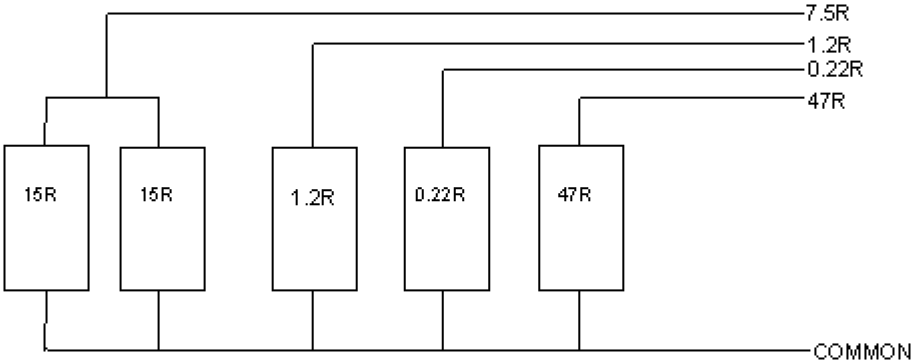


Test Load Box

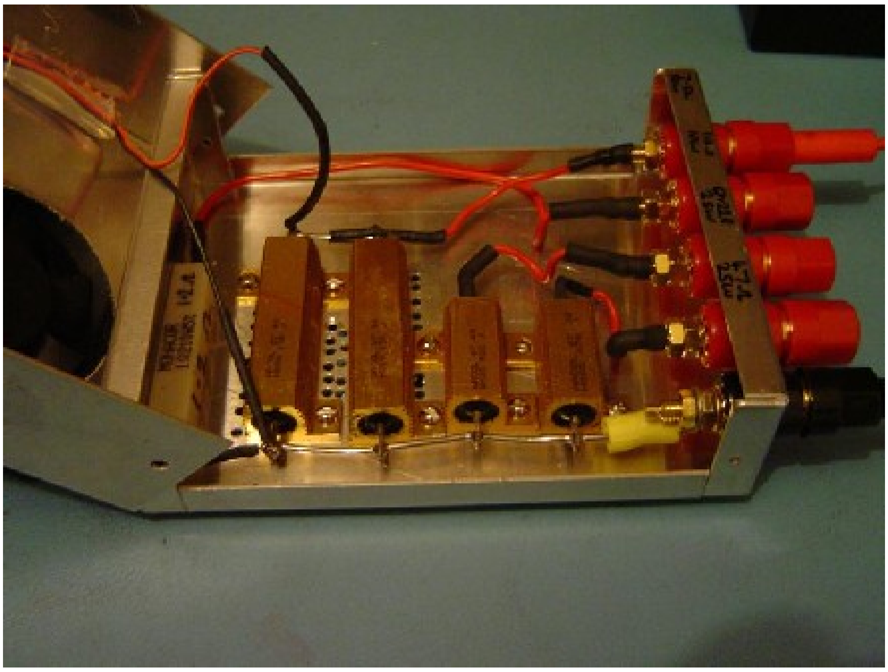
The test loads are housed within an aluminium casing. Each load is brought outside the box using banana terminals. The test box contains the following loads:

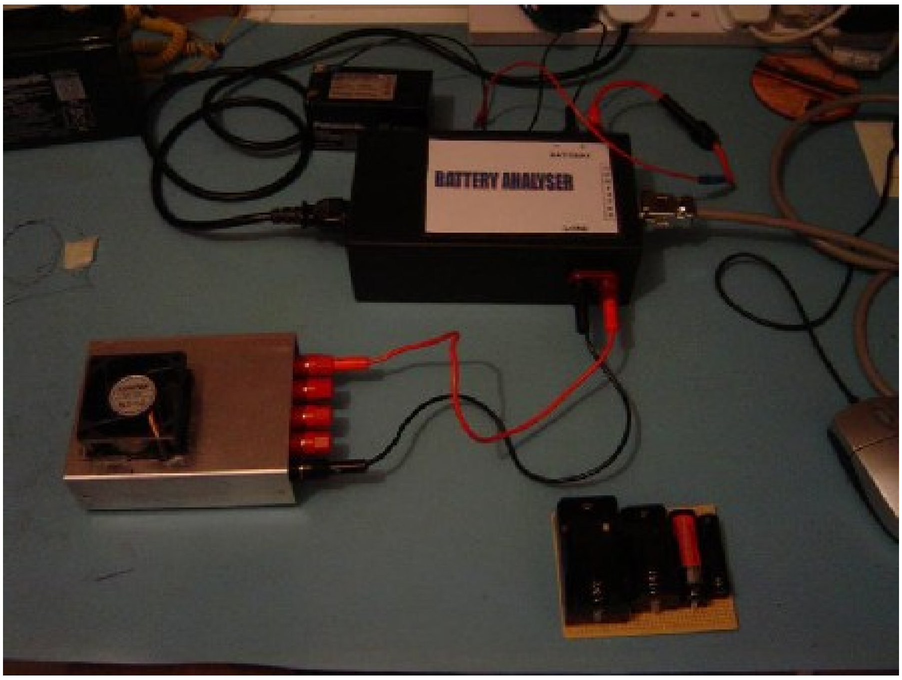
Load	Suitable Use
2 x 15R (50W) Resistors in Parallel = 7R5	6V & 12V batteries at about 1.7 Amps
1.2R (10W) (Plus 0.1R shunt resistor)	1.2 - 1.5V lower capacity batteries Typical discharge current is 1 Amp.
0.22R (25W) (Plus 0.1R shunt resistor)	0.22R (25W) (Plus 0.1R shunt resistor)
47R (25W)	9V batteries. Typical discharge current is 0.2 Amps.

Note. If used as above, heat dissipation won't be a problem. Only the two 15R resistors in parallel will get hot. With a fully charged 12V battery, the maximum temperature of the resistors was measured to be 60°C. By placing a 12V fan across the two resistors, and drilling ventilation holes around the resistors, the temperature dropped to less than 50°C. The resistors are rated at 200°C.



Basic Circuit Diagram of Load Box





Calibration

The analyser was powered up with a 12v, 20W lamp as a load and a 12V, 1300mAh Lead Acid battery.

Voltage Calibration
The analyser was set to measure battery voltage and the output of the AtoD converter recorded. The AtoD converter output will be a value between 0 and 4096 (12 bit AtoD). To calibrate the output, we need to measure the actual battery voltage using a DMM.

AtoD Output	Actual Battery Voltage
3620	12.17V

If we now divide the AtoD Output by the battery voltage we get a calibration factor of : 3620 / 12.17 = 297.5
For the software to display the actual battery voltage all it needs to do is divide the AtoD output by the calibration factor.

Current Calibration
The analyser was set to measure current and as above, the AtoD converter output recorded. The actual current was measured using a DMM in series with the battery and load.

AtoD Output	Actual Battery Current
1860	1546mA

If we now divide the AtoD Output by the current we get a calibration factor of : 1860 / 1546 = 1.203
For the software to display the actual current all it needs to do is divide the AtoD output by the calibration factor.

Measurement of Cal Factor at lower level of Load current
A 1.2V, 2600mAh NiMi battery was used with the 12V, 20W lamp.

<<<Voltage>>>

AtoD Output	Actual Battery Voltage	Cal Factor
327	1.140	286.8

<<<Current>>>

AtoD Output	Actual Battery Current	Cal Factor
636	523mA	1.216

Analyser Linearity
Now that the Cal Factor has been calculated at two different levels, we can work out the linearity of the analyser. At 12V the cal factor is 297.5. At 1.2V the cal factor is 286.8. The percentage difference between the two cal factors is: 3.6%. So, the analyser can measure the battery voltage with a linearity of at least 3.6% between 1.2V and 12V

Likewise, for Current:
Cal factor at 523mA = 1.216
Cal Factor at1546mA = 1.203
Linearity between 523mA and 1546mA = 0.25%

NOTE : This circuit is only suitable for analysing batteries up to a maximum of 14V. By up-rating the relay there should be no problems with using higher voltage batteries and higher current loads, although the shunt resistor may also have to be up-rated or mounted on a heat sink.

Interfacing with the Parallel Port

The Data Register and the Status Register of the parallel port are used to interface with the analyser. This can be implemented fairly easily using Visual Basic 6 or MS QuickBasic.

Data Register - Parallel Port Output/Input Lines

Parallel Port Data Register	b0	b1	b2	b3	b4	b5	b6	b7
Circuit Board Connection	A0	A1	A2	CS	SCLK	RELAY CONTROL	NC	NC
Description	DG508A Multiplexor Input Select			MAX 187 AtoD		Switched Load	NC	NC

Status Register
Bit 5 of the Status Register is connected to Dout of the Max 187 AtoD.

M**AX 187 12bit Serial AtoD Converter Pin out**

1	VDD	Supply voltage, +5V ±5%
2	Ain	Sampling analogue input, 0V to VREF range
3	SHDN	Pulling SHDN high enables the internal reference
4	REF	Reference voltage - Sets analogue voltage range to 4.096V.
5	GND	Digital ground
6	Dout	DOUT Serial data output. Data changes state at SCLK's falling edge.
7	CS	Active-low Chip Select initiates conversions on the falling edge. When CS is high, DOUT is high impedance.
8	SCLK	Serial clock input. Clocks data out with rates up to 5MHz.

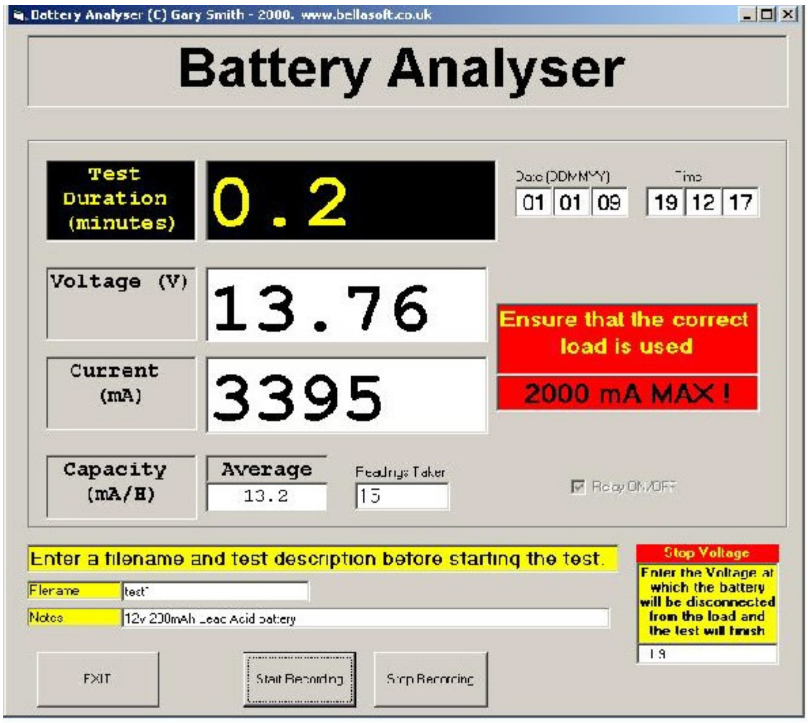
DG508 Multiplexer Pin out

1,15,16	A0, A1, A2	Address Inputs
2	EN	Enable. Take high to enable the IC
3, 13	V+, V-	Supply Voltage +/- 18V max
4,5,6,7,9,10,11,12	S1 to S7	Signal Input Lines
8	D	Switched Singal Output
14	GND	Ground (0v)

A 9 pin D type socket was selected for the battery analyser housing. A standard 25 pin D-type printer cable was used and a 9 pin D-type plug placed on the other end connected as below

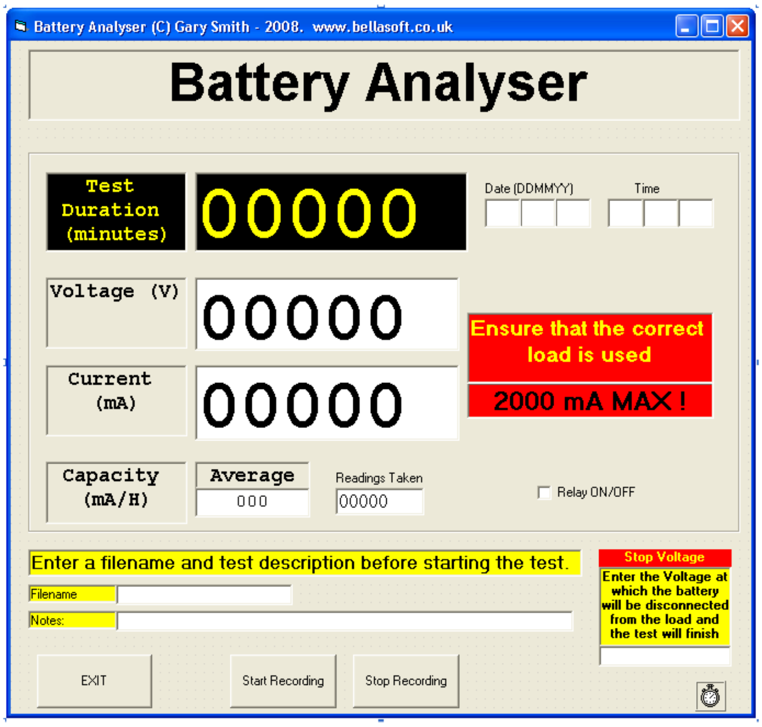
25 pin D-type connected to PC Parallel Port		9 Pin D-type	Parallel Port Output / Input	Circuit Connection
Pin Number	Wire Colour	Pin Number		
2	Red	5	Data 0	Muliplexer A0
3	Orange	4	Data 1	Multiplexer A1
4	Pink	3	Data 2	Multiplexer A2
5	Yellow	2	Data 3	AtoD CS
6	Green	1	Data 4	AtoD SCLK
7	Light Blue	6	Data 5	Relay Control
11	White	7	Busy	AtoD Dout
25	Black/Grey	8	GND (0v)	GND (0v)

Software Screenshot



Visual Basic Project

Sensors.frm



Program Modules

InpOut32_Declarations

```
'Inp and Out declarations for port I/O using inpout32.dll.


Public Declare Function Inp Lib "inpout32.dll" Alias "Inp32" _
    (ByVal PortAddress As Integer) _
    As Integer

Public Declare Sub Out Lib "inpout32.dll" Alias "Out32" _
    (ByVal PortAddress As Integer, _
    ByVal Value As Integer)

Function BitStatus(PortNum%, BitYouWant%) As Integer
    NumOfBits% = 8
    ReDim PortBits(NumOfBits%) As Integer
    For i = 1 To NumOfBits%
        PortBits%(i) = PortNum% Mod 2
        PortNum% = Fix(PortNum% / 2)
    Next i
    BitStatus = PortBits%(BitYouWant%)
End Function

Function user_delay(delay) As Integer
    Dim n As Single
    n = Timer
    While Timer - n < delay: Wend
End Function
```

```
Function get_data(input_select, atod_output) As Integer
        Dim status_total As Integer
        Dim PortAddress As Integer
        'Change PortAddress to match the port address to write to:
        '(Usual parallel-port addresses are &h378, &h278, &h3BC)
        PortAddress = &H378
        ' put tick in relay on/off box
        sensors.relay.Value = 1
        atod_output = 0
        Out PortAddress, 32 + 8 + input_select 'CS High  SCLK Low -
        Out PortAddress, 32 + 0 + input_select  'CS Low   SCLK Low - Start a conversion
        ' Get bit of data
        For n = 11 To 0 Step -1
                ' Clock SCLK - Get bit of data
                Out PortAddress, 32 + 16 + input_select  'CS Low  SCLK High
                Out PortAddress, 32 + 0 + input_select 'CS Low  SCLK Low
                ' Read Status Port
                status_total = Inp(PortAddress + 1)
                status_total = 255 - status_total
                ' Get status of b7 (status port) - 1 or 0.
                status_total = BitStatus(status_total, 8)
                If status_total = 1 Then atod_output = atod_output + (2 ^ n)
        Next n
        DoEvents
End Function


Function select_input_channel(input_select) As Integer
        ' First select input channel
        Out PortAddress, input_select
        ' Small delay while Multiplexor switches input channels
        Call user_delay(0.2)
End Function


Function toggle_relay() As Integer
        Dim PortAddress As Integer
        PortAddress = &H378
        If sensors.relay.Value = 1 Then Out PortAddress, 32
        If sensors.relay.Value = 0 Then Out PortAddress, 0
End Function


Function relay_off() As Integer
        Dim PortAddress As Integer
        PortAddress = &H378
        Out PortAddress, 0
End Function
```

```
Option Explicit
Dim Value As Integer
Dim input_select As Integer
Dim atod_output As Integer
Dim atod_voltage As Single
Dim atod_current As Integer
Dim atod_avg As Long
Dim monitor_flag As Boolean
Dim elapsed As Long
Dim avg_current As Single
Dim max_current As Single
Dim total_current As Single
Dim readings As Long


Private Sub button_exit_Click()
       ' Turn off relay before exiting program
       sensors.relay.Value = 0
       Call toggle_relay
       End
End Sub


Private Sub button_start_recording_Click()
Dim lop As Integer
Dim response
relay.Enabled = False
monitor_flag = True
If Text_vstop.Text = "" Then
       response = MsgBox("You need to enter the voltage at which the battery will be disconnected.
       Failure to do this will result in the battery being disharged to 0 Volts. Enter a value in the
       Stop Voltage box.  You can enter this value during the test. ", vbOKOnly, "WARNING")
End If
elapsed = 0
avg_current = 0
max_current = 0
total_current = 0
readings = 0

Open Text_filename.Text + ".txt" For Append As #1
Print #1, Text_description.Text
Close #1

While (monitor_flag = True)
    DoEvents
    Rem ***********************************************
    Rem ***** input select : 0=voltage, 1=current *****
    Rem ***********************************************
    For input_select = 0 To 1
        ' Take a reading
        ' Select voltage or current input to multiplexer
```

```
            Call select_input_channel(input_select)


        ' Get Average of 100 readings
        atod_avg = 0
        For lop = 1 To 1000
        ' Get AtoD output
            Call get_data(input_select, atod_output)
            atod_avg = atod_avg + atod_output
        Next lop
        atod_output = atod_avg / 1000


        ' Display AtoD Output Voltage
        If input_select = 0 Then
               atod_voltage = atod_output / 297.5
               ' Set number of decimal places depending on battery voltage
               If atod_voltage > 10 Then atod_voltage = Round(atod_voltage, 2) Else atod_voltage =
               Round(atod_voltage, 3)
               text_atod_output(input_select).Text = atod_voltage
         End If
        If atod_voltage < Val(Text_vstop.Text) And elapsed > 5 Then monitor_flag = False
        ' Current
       If input_select = 1 Then
               atod_current = atod_output / 1.203
               atod_current = atod_current - 9
               text_atod_output(input_select).Text = atod_current
               total_current = total_current + atod_current
               readings = readings + 1
               avg_current = total_current / readings
               Text_avg.Text = Round(avg_current * (elapsed / 3600), 1)
               Text_readings.Text = readings
       End If
    Next input_select

    ' Add test results to the file
    Open Text_filename.Text + ".txt" For Append As #1
    Print #1, Label_elapsed_m, text_atod_output(0).Text, text_atod_output(1).Text
    Close #1
    Label_elapsed_m.Caption = Round(elapsed / 60, 1)
Wend

' Turn off lamp
Call relay_off
relay.Value = False
response = MsgBox("The test has finished", vbOKOnly, "Finished")
relay.Enabled = True
Open Text_filename.Text + ".txt" For Append As #1
Print #1, "*********************************************"
Print #1, "** BATTERY CAPACITY (mAh)"
Print #1, "**"
Print #1, "**  "; Text_avg.Text
Print #1, "**"
```

```
Print #1, "*********************************************"
Close #1
End Sub
Private Sub button_stop_recording_Click()
        monitor_flag = False
End Sub

Private Sub relay_Click()
Call toggle_relay
End Sub

Private Sub Timer1_Timer()
        ' Only enable the start button once a filename and description have been entered
        elapsed = elapsed + 1
        If Text_filename.Text <> "" And Text_description.Text <> "" Then
                button_start_recording.Enabled = True
                Else: button_start_recording.Enabled = False
        End If
        ' Display the date and time
        Text_seconds = Mid$(Time, 7, 2)
        Text_mins = Mid$(Time, 4, 2)
        Text_hours = Mid$(Time, 1, 2)
        Text_day = Mid$(Date, 1, 2)
        Text_month = Mid$(Date, 4, 2)
        Text_year = Mid$(Date, 9, 2)
        If Label12.ForeColor = vbYellow Then Label12.ForeColor = vbBlack Else Label12.ForeColor = vbYellow
End Sub


Private Sub y_Click()
        Call relay_off
End
End Sub
```