A REPORT

ON

IOT BASED PROGRAMMABLE RESISTIVE LOAD BANK

BY

Abizer Luqmanji 2018A3PS1001G

AT

Electrono Solutions - Industrial Control & Automation, Bangalore

A Practice School-I Station of

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI

(June, 2020)

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Abizer Luqmanji 2018A3PS1001G Electrical and Electronics Engineering

Prepared in partial fulfilment of the
Practice School-I Course No.
BITS F221

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(RAJASTHAN)
Practice School Division

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Title of Project: IoT Based Programmable Resistive Load Bank

ID No.: 2018A3PS1001G
Name: Abizer Luqmanji
Discipline: Electrical and Electronics Engineering

Name and Designation of Experts:
Mr. Nikhil A G — Remote Engineering Designer
Mr. Ian Pereira — Remote Engineering Designer
Mr. P.S Hiremath — Technical Director

Name of PS Faculty: Professor Rakesh R. Warier

Key Words: IoT, Load Banks

Project Areas: Control Systems, Electrical Machines

Abstract:
To design a three phase variable resistive load bank with a maximum capacity of 12kW and 10 step control.

Signature of Student
Date: 26 June, 2020

Signature of PS Faculty
Date:

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INTRODUCTION

A Load Bank is a device which develops an electrical load, applies the load to an electrical power source and converts or dissipates the resultant power output of the source. A Load Bank is intended to accurately mimic the operational or “real” load which a power source will see in actual application.

However, unlike the “real” load, which is likely to be dispersed, unpredictable and random in value, a Load Bank provides a contained, organized and fully controllable load. Consequently, a Load Bank can be further defined as a self-contained, systematic device which includes both load elements with control and accessory devices required for operation.

Load Banks can be used for several purposes, including:

- Generator Test Cells: Manufacturers of standby power generators commonly use load banks to test and tune newly assembled units.
- Engine Test Cells: Manufacturers of small gas engines also use load banks to test newly manufactured engines under various mechanical loads. This is accomplished by connecting the engine to the load bank via a device called a dynamometer and adjusting the engine parameters.
- Field Testing & Exercise: Generators installed in the field must be periodically tested and exercised to ensure that it will operate as intended when a power outage actually occurs. Service groups use load banks to apply a load that mimics the load of the facility the generator is protecting. Any problems with the generator can then be identified and rectified in a non-critical environment.
- Elimination of Wet Stacking: If a diesel engine is not operated under adequate load, unconsumed fuel will collect in the engine’s exhaust stack and form an oily coating. Load banks may be installed in a diesel powered generator set to apply the additional load required to ensure the engine fully consumes the fuel in the combustion process.

There are three main types of load banks, namely

- Resistive Load Banks: provides equivalent loading of both generator and prime mover
- Reactive Load Banks: includes inductive (lagging power factor) and/or capacitive (leading power factor) loads
- Resistive/Reactive Load Banks: combine both resistive and reactive elements in one load bank package

PROJECT MILESTONES

These are the milestones that I have completed over the course of my project:

1. Voice of Customer Document
2. Basic Block Diagram
3. Detailed Block Diagram
4. Process Flow Chart
5. Bill of Materials
6. Schematic Diagram
7. Wiring Diagram
8. LabVIEW Front Panel

VOICE OF CUSTOMER DOCUMENT

Three phase variable resistive load bank with 12kW maximum capacity and 10 variable step control. All resistors are connected in 3 phase star formation.

Sl no	Customer requirement	Input	Output
1	Step 1	3x 690Ω resistors (90W rating)	250W, 0.35A
2	Step 2	3x 690Ω resistors (90W rating)	250W, 0.35A
3	Step 3	3x 344Ω resistors (175W rating)	500W, 0.70A
4	Step 4	3x 172Ω resistors (500W rating)	1kW, 1.39A
5	Step 5	3x 172Ω resistors (500W rating)	1kW, 1.39A
6	Step 6	3x 172Ω resistors (500W rating)	1kW, 1.39A
7	Step 7	3x 86Ω resistors (750W rating)	2kW, 2.78A
8	Step 8	3x 86Ω resistors (750W rating)	2kW, 2.78A
9	Step 9	3x 86Ω resistors (750W rating)	2kW, 2.78A
10	Step 10	3x 86Ω resistors (750W rating)	2kW, 2.78A

Rated 3 phase voltage, V_{Line} = 415V, and V_{phase} = 239.60 V

For star connected circuit,

$V_{phase} = V_{line} / \sqrt{3}$

$I_{line} = I_{Phase}$

$R_{Phase} = V_{Phase} / I_{phase}$

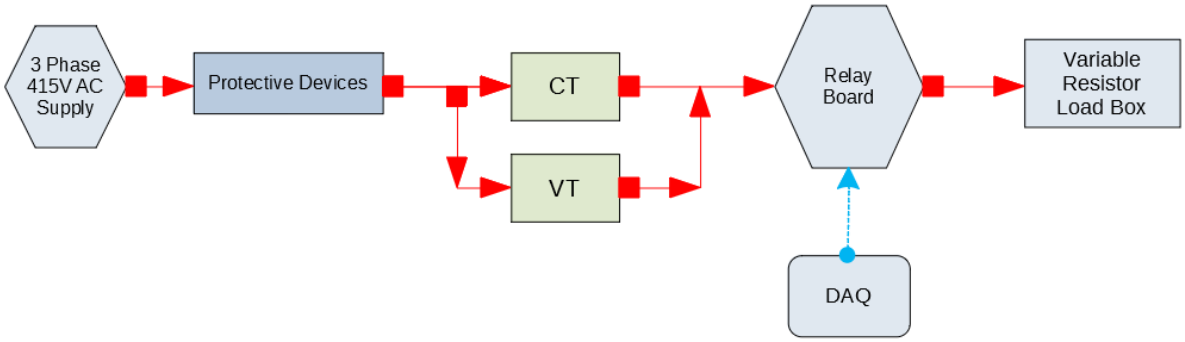
Equal steps can also be triggered for the following loads.

Equal Steps	Load per Step	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
2	6000	1,2,3,4,5,6,7	8,9,10				
3	4000	1,2,3,4,5,6	7,8	9,10			
4	3000	1,2,3,7	4,8	5,9	6,10		
6	2000	1,2,3,4	5,6	7	8	9	10

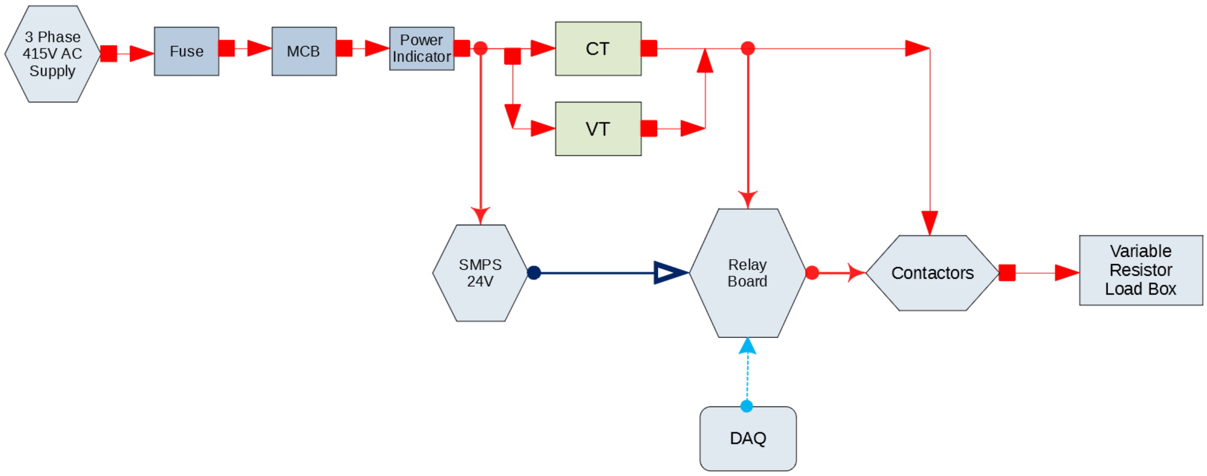
Each of these emulated equal steps will switch on one or more physical steps to attain the required load value.

BLOCK DIAGRAM

The block diagram represents the basic flow of the circuit. It is used as the initial step in developing a more detailed schematic and wiring diagram.



Basic Block Diargam

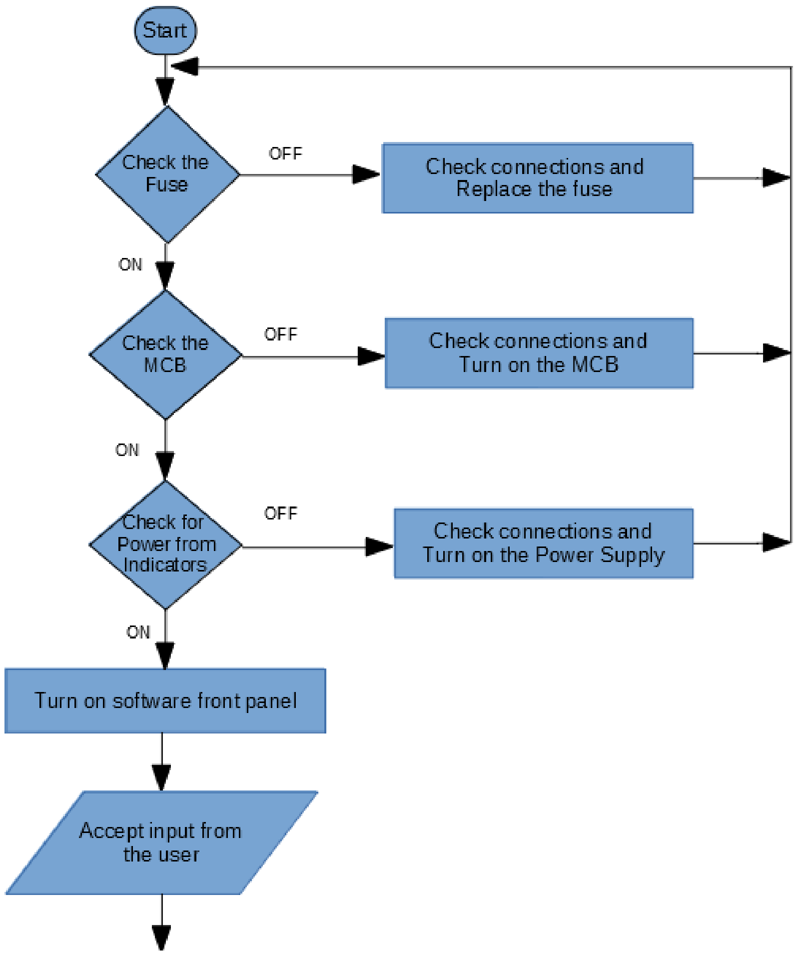


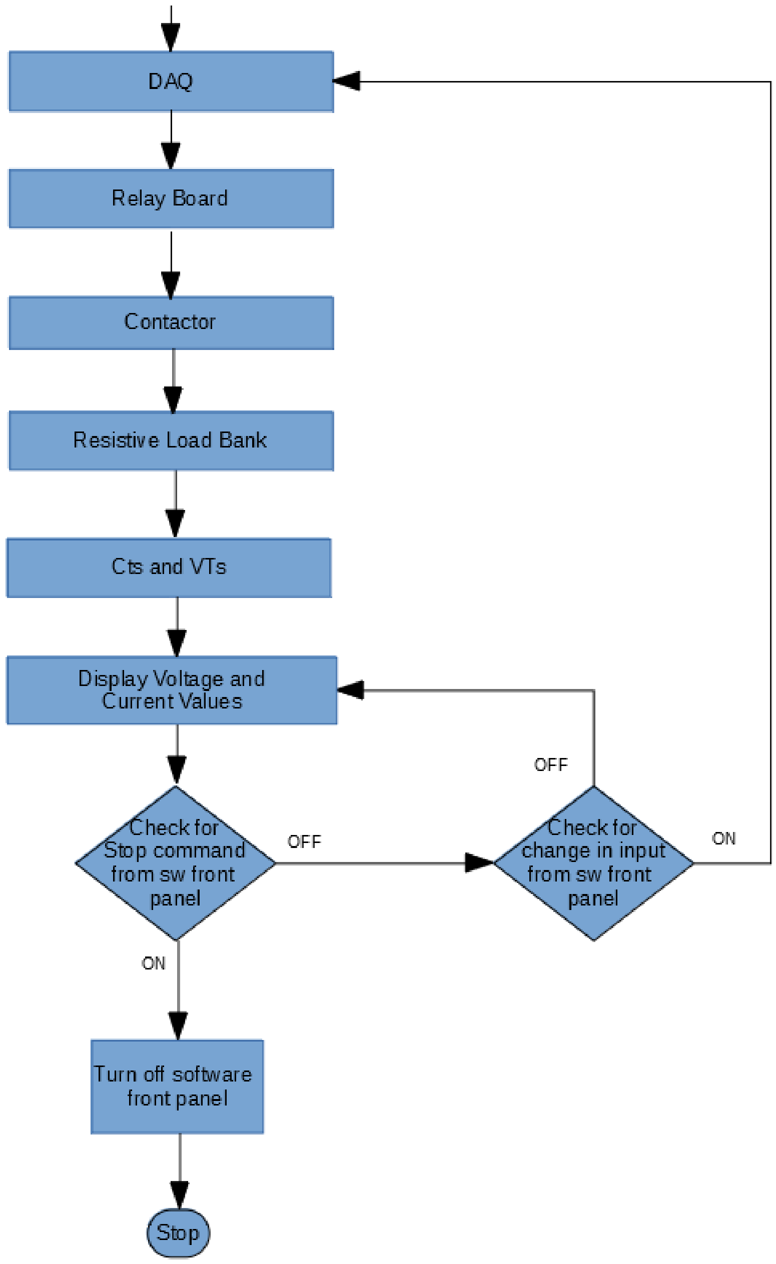
Detailed Block Diagram

In the above block diagrams, CT and VT are current and voltage transformers respectively. They are responsible for measuring the current and voltage of the circuit and displaying it on the front panel of the device.

PROCESS FLOW CHART

A flowchart is a visual representation of the sequence of steps and decisions needed to perform a process. The user can consult the flow chart to understand how to operate the device and it can also be a useful tool for troubleshooting.




DAQ
Relay Board
Contactor
Resistive Load Bank
Cts and VTs
Display Voltage and Current Values
Check for Stop command from sw front panel
OFF
Check for change in input from sw front panel
OFF
ON
ON
Turn off software front panel
Stop

BILL OF MATERIALS

A bill of materials (BOM) is a comprehensive inventory of the parts and components, as well as the quantities of each, needed to manufacture a product. I have listed each of these components with their price and vendor.

Sl.No	Category	Components	Description/Specifications	Qty	Unit Cost	Total Cost	Vendor Details	Reference
1	Power Supply	24V SMPS	NHP 24V 3A 72W Switch Mode Power Supply	1	₹959.00	₹959.00	Robu.in https://robu.in/product/nhp-24v-3a-7	
2		Fuse	SKYU Bakelite Kit Kat Fuse, 20A 250VAC	3	₹80.00	₹240.00	Indiamart https://www.indiamart.com/proddeta	
3	Protective Devices	MCB	Havells MCB FP D CURVE 20 A 4 Pole	1	₹1,760.00	₹1,760.00	Havells https://www.havells.com/en/consum	
4		3 Phase Voltage Indicator	Schneider Electric Pilot light 3 phases voltage, indicator with 3 LED, white, 400 V AC	1	₹17,716.12	₹17,716.12	Element 14 https://in.element14.com/schneider-	

I have included a 24V DC power supply to power the relay boards along with protective devices such as fuses, an MCB, and a three phase power indicator.

5	Contactors	Main Contactor	Schneider Electric EasyPact TVS contactor 3P(3 NO) - AC-3 - <= 440 V 18A - 415 V AC coil	1	₹801.00	₹801.00	industrybuying.com https://www.industrybuying.com/con	
6		Branch Contactor	Schneider Electric EasyPact TVS contactor 3P(3 NO) - AC-3 - <= 440 V 6A - 415 V AC coil	10	₹611.00	₹6,110.00	industrybuying.com https://www.industrybuying.com/con	
7	Relay Boards	Single Channel Relay	SPDT channel relay with 24VDC power supply and 42mA current consumption	1	₹129.00	₹129.00	Robu.in https://robu.in/product/24v-1-channe	
8		10 Channel Relay	10 SPDT channel relay board with 24VDC power supply and 210mA current consumption	1	₹2,009.06	₹2,009.06	Denkovi Assembly Electronics http://denkovi.com/relay-card-24v-10	

I have used an 18A rated contactor for the main switch and 10 6A contactors for the 10 individual steps. The single channel relay board excites the main contactor and the 10 channel relay board is used to excite the 10 step contactors from the DAQ.

9	Data Acquisition	DAQ	NI USB-6501 24-Channel, 8.5 mA, Digital I/O Device	1	₹9,400.00	₹9,400.00	National Instruments https://www.ni.com/en-in/shop/selec	
10		Multifunction Meter	Schneider Electric EasyLogic PM2130, Power & Energy meter, up to 31stH, LED, RS485, class 0.5S	1	₹23,622.63	₹23,622.63	Nex Instruments https://www.nexinstrument.com/ME	
11		Current Sensor	Schneider Electric Current transformer tropicalised DIN mount 40 5 for cables d. 21	3	₹2,999.90	₹8,999.70	Elect Go https://sg.electgo.com/products/ME	
12	Indicators	LED Indicators for Individual Steps	LED PANEL INDICATOR 230V 22MM	10	₹335.00	₹3,350.00	Tsktech.in https://www.tsktech.in/product/led-p	

The NI USB-6501 DAQ is used since it has 24 digital I/O pins and I needed a minimum of 11 pins. The multifunction meter is used alongside the current transformers to read and display the current and voltage values on the front panel. 10 LED indicators are used to indicate when each step is turned on.

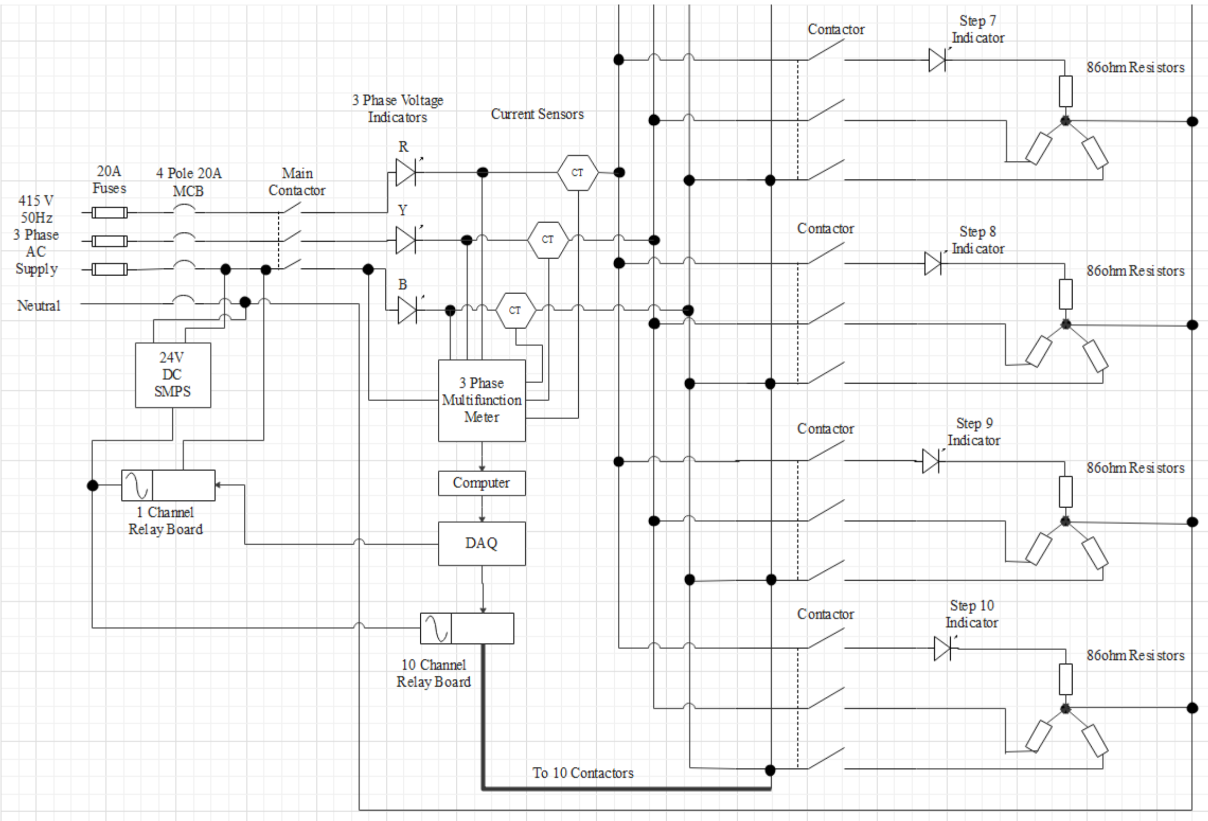
13	Resistors	690 ohm (90W)	Vishay Wirewound Resistors, Industrial Power, Tubular, Roundwire (RD), Fixed (RDEF, RDSF) RDEF0090	6			Vishay https://www.vishay.com/resistors-fix	
14		344 ohm (175W)	Vishay Wirewound Resistors, Industrial Power, Tubular, Roundwire (RD), Fixed (RDEF, RDSF) RDEF0175	3			Vishay https://www.vishay.com/resistors-fix	
15		172 ohm (500W)	Vishay Wirewound Resistors, Industrial Power, Tubular, Roundwire (RD), Fixed (RDEF, RDSF) RDSF0500	9			Vishay https://www.vishay.com/resistors-fix	
16		86 ohm (750W)	Vishay Wirewound Resistors, Industrial Power, Tubular, Roundwire (RD), Fixed (RDEF, RDSF) RDSF0750	12			Vishay https://www.vishay.com/resistors-fix	

I have gone with resistors from Vishay's RDEF/RDSF line as they match the requirement for resistor values as well as power rating.

Apart from these main components I have made use of electrical components such as 12A and 24A cables, cooling fans, and other hardware components to organize the various components inside the device enclosure.

SCHEMATIC DIAGRAM

A schematic diagram is a picture that represents the components of a process, device, or other object using abstract, often standardized symbols and lines. Starting from my block diagram, I have made a schematic diagram to represent how the various components are connected to each other.

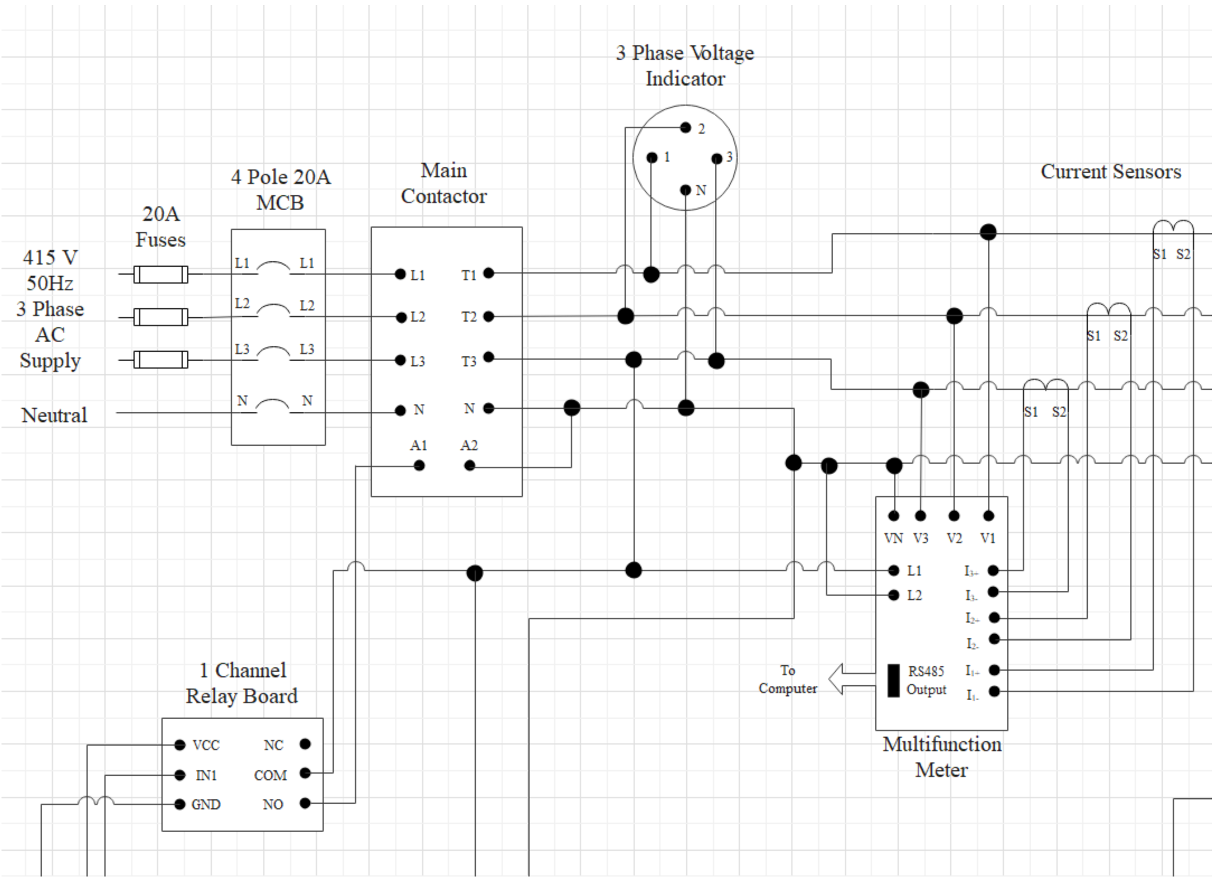


This snapshot of the schematic diagram only includes 4 of the 10 steps. The other 6 steps are identical to these steps in all aspects apart from the resistor value.

A major learning step for me was learning about the functions of a DAQ and multifunction meter in an electronic device. In this case, the DAQ serves as an intermediary between the remote software panel and the machine, as it relays the user input to the relay board and hence to the contactors. The multifunction meter simply reads the current and voltage values and displays them on the front panel as well as transfers the reading to the computer to be displayed on the software front panel.

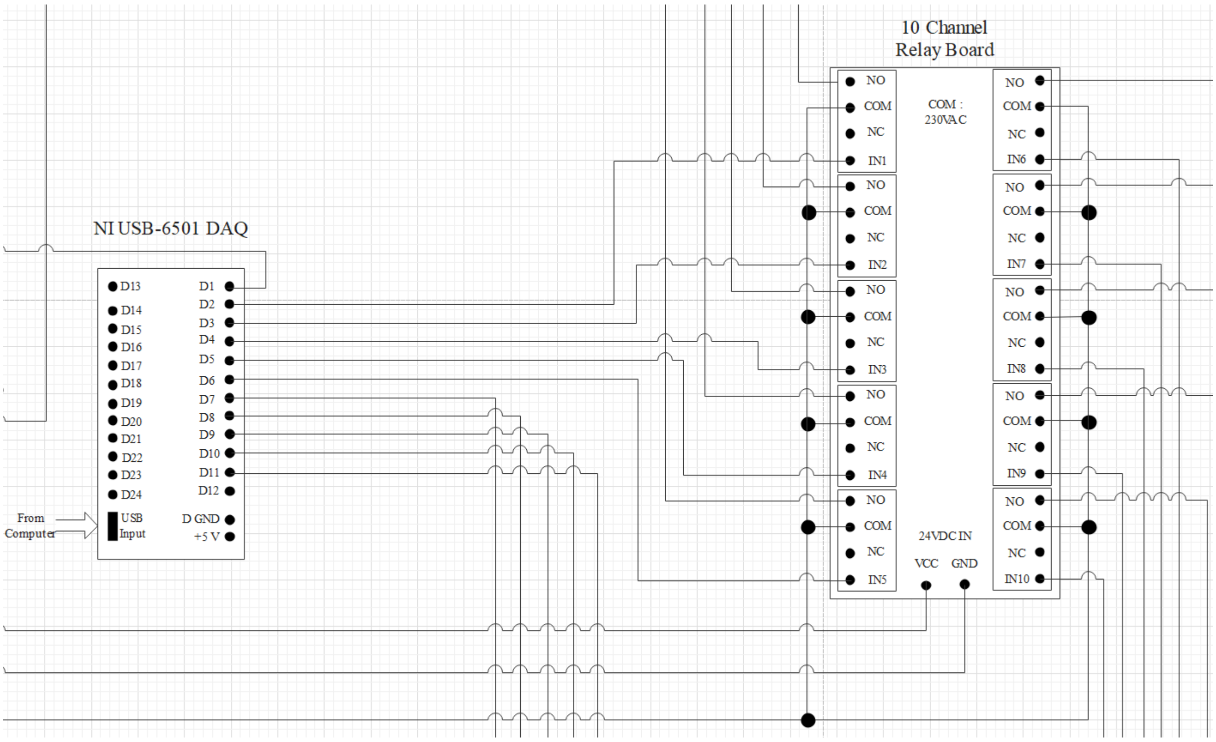
WIRING DIAGRAM

A wiring diagram is a simplified conventional pictorial representation of an electrical circuit. It shows the components of the circuit as simplified shapes, and the power and signal connections between the devices. This diagram is basically the schematic diagram in which the connections between the terminals of each component is shown. This is the most detailed representation of the final device and can be referenced while building the physical circuit.

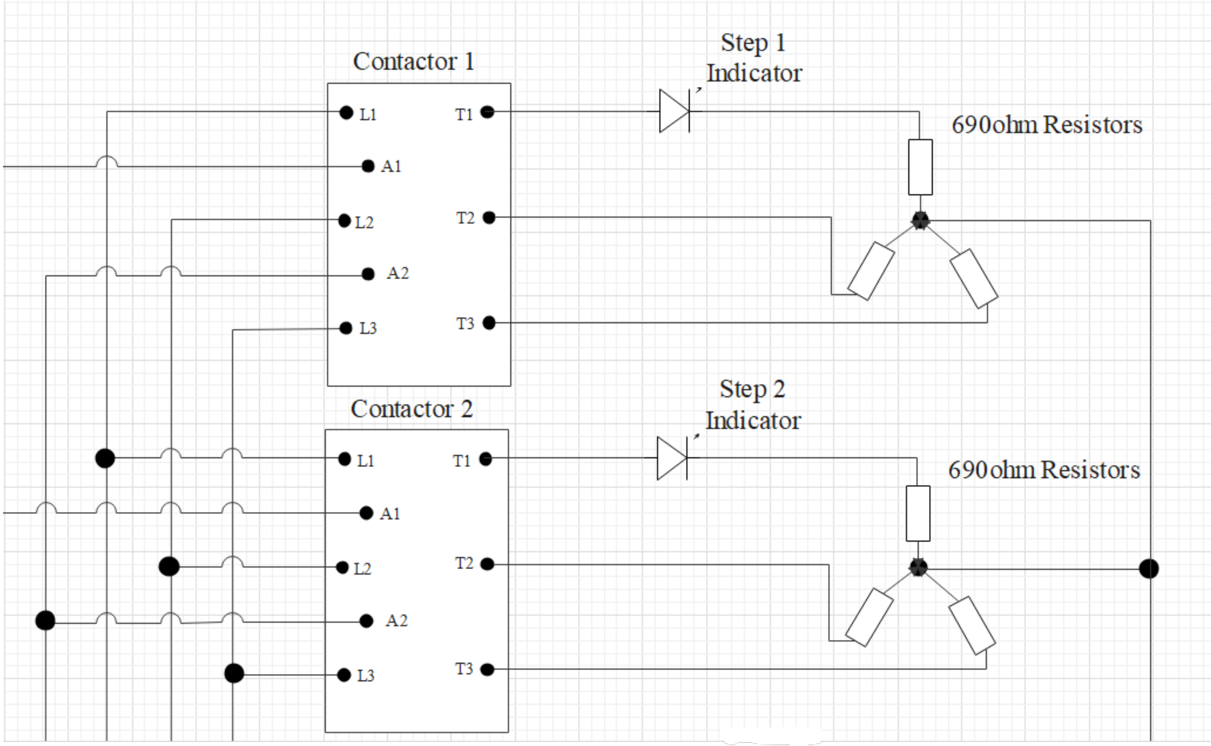


This snapshot shows the connections between the various terminals of the main contactor and the relay board. To excite the contactor, there should be a potential difference of 230VAC between the A1 and A2 terminals. To achieve this, the common terminal of the relay board is connected to 230VAC and the normally open terminal is connected to A1. A2 is always connected to neutral. When an ON signal is sent from the DAQ to IN1 of the relay board, the COM and NO terminals get connected and 230VAC is applied between A1 and A2, exciting the contactor. This principle is used for the other 10 contactors as well.

The multifunction meter has built-in voltage transformers but makes use of external current transformers to read the current. These reading are then sent to the computer via an RS 485 interace.



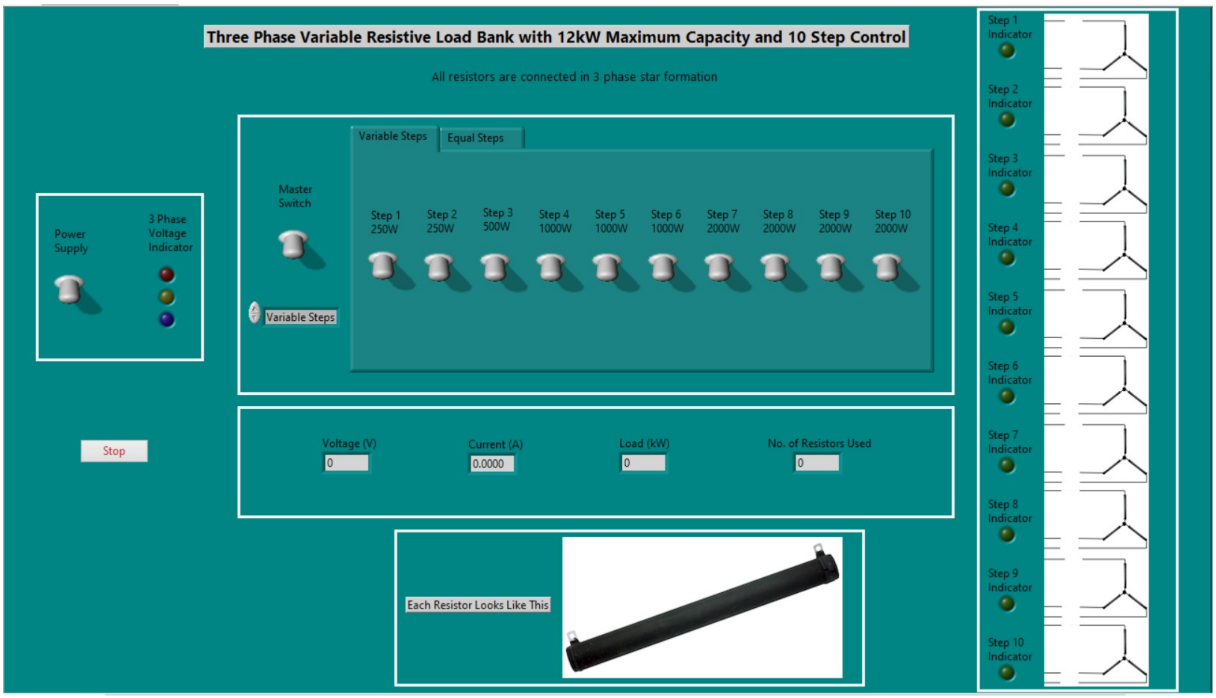
This snapshot shows the terminals of the DAQ and the 10 channel relay board. The DAQ is powered by the USB cable from the computer. The relay board is powered by a 24 VDV SMPS. The first digital I/O port of the DAQ is connected to the input terminal of the single channel relay shown in the previous snapshot, while the next 10 ports are connected to the input terminals of the 10 channel relay board respectively. Similar to the first relay board, the COM terminal of each channel is connected to 230VAC and the NO terminal is connected to the corresponding step contactor.



This snapshot shows 2 of the 10 load steps. The A1 terminals of each contactor are connected to the NO terminals of the corresponding channels of the 10 channel relay board. The A2 terminals are connected to neutral. All the resistors are connected in 3 phase star formation. Each step is identical apart from the value of resistors used.

LABVIEW FRONT PANEL

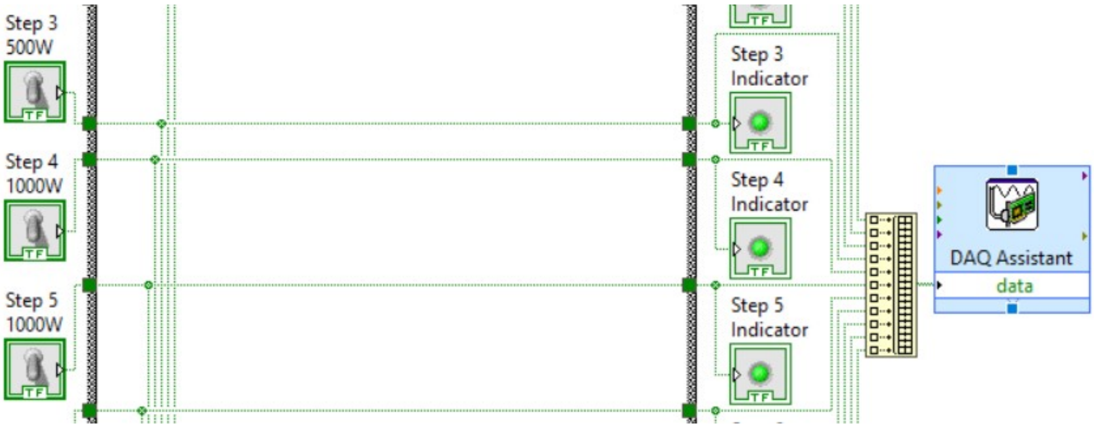
While designing my front panel on LabVIEW, I have focused on simplicity to deliver an easy to use user interface. The front panel includes options for variable as well as equal stepping.



The front panel includes switches for the power supply, an indicator to show that the power supply is functioning nominally, and a master switch followed by switches for each individual load step. I have used tabs to differentiate between variable steps and equal steps. Below the switches are indicators that show the value of voltage, current, total load and number of resistors being used. On the right side, there is a graphic that shows the resistors connected in star formation in each step and a light indicator to show if any step is currently switched on. There is also a picture of the actual resistor to show the user what the resistors look like.

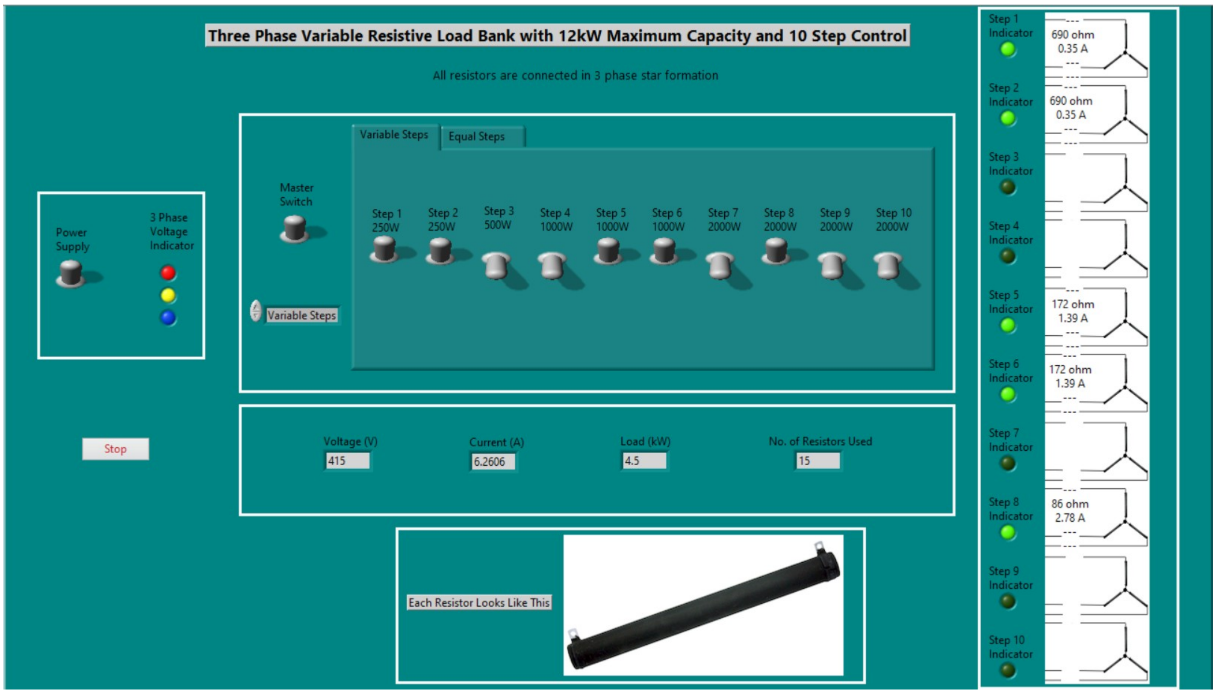
Since we do not have access to a DAQ, I have simulated the DAQ using drivers from NI. The voltage and current reading in an actual system would come from the multifunction meter but as I do not have access to one I have calculated these values in the program itself.

The master switch and each of the 10 variable step switches are connected directly to the digital output ports of the DAQ.



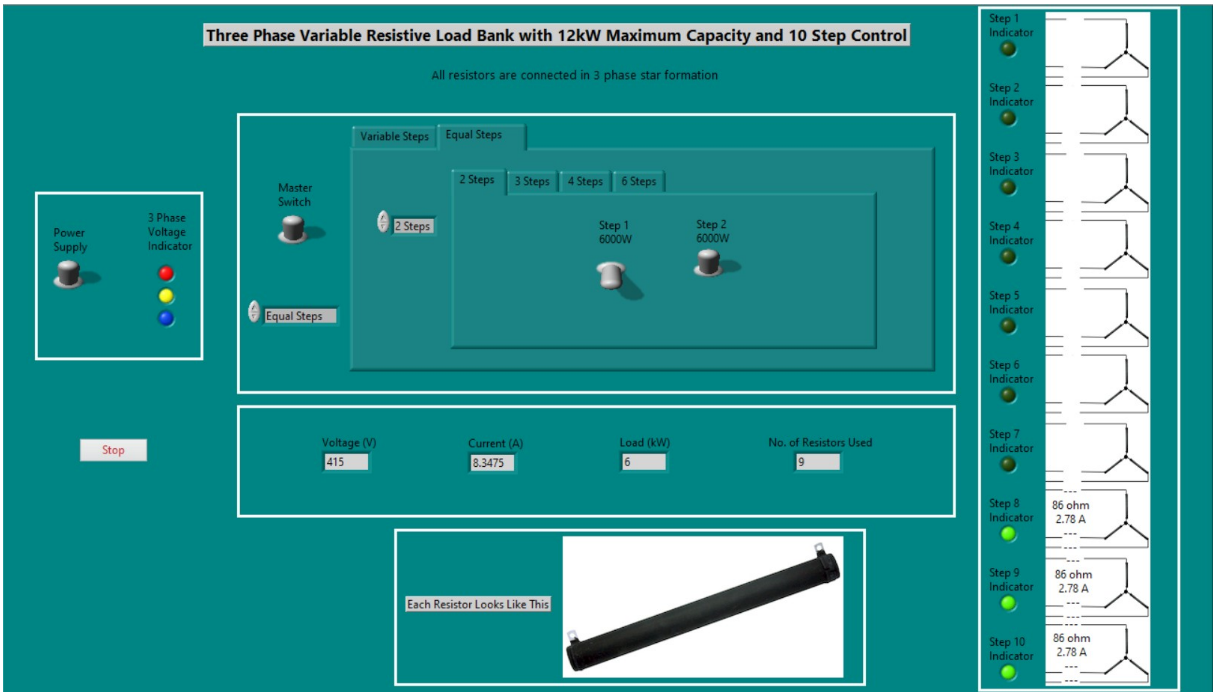
This a snapshot from the block diagram that shows how the load steps are connected to the DAQ.

Example of Variable Stepping:

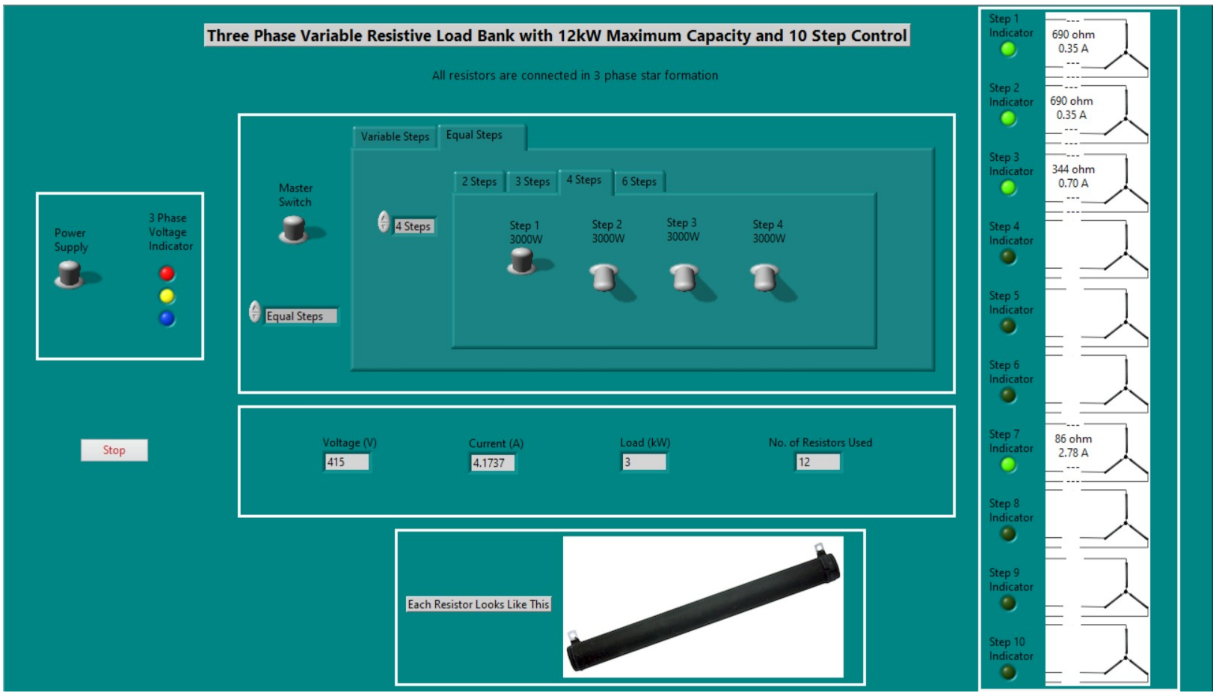


Here Step 1, 2, 5, 6 and 8 have been selected adding up to a total load of 4.5kW. The resistor values and current in each step can be seen in the graphic to the right, alongside the green LED indicator.

Examples of Equal Stepping:



In this example, the second switch for 6kW equal stepping is triggered which intern triggers the last three steps of 2kW each to achieve a total of 6kW.



In this example, the first switch for 3kW equal stepping is switched on which triggers step 1, 2, 3 and 7 in order for the load to add up to 3kW.

CONCLUSION

Working on this project has greatly increased my understanding of load banks and the electronic components used in them.

The structure of the project, beginning with the voice of customer document, block diagram and flow chart, schematic diagram, wiring diagram, bill of materials and finally the LabVIEW front panel has given me an insight as to how engineering projects are actually executed.

Our daily meetings with the industry professionals along with working on the project on LabVIEW have given me a glimpse into the professional electrical industry.

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