Republic OF Yemen
Ministry OF Higher Education
And Scientific Research
Emirates OF International University
Faculty OF Engineering
And International Technology

Multiple Power Management System Using SCADA

Preparing Students

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Graduation project report submitted to the Engineering Department in partial fulfillment of the requirements for the bachelor's degree in mechatronics

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Summary

- **Introduction statement**

Multiple energy management systems using SCADA (intelligent central distribution control system) are a modern and innovative technology used to monitor and control energy consumption, monitor solar panels and batteries, determine which ones are faulty and do not generate energy, and are equipped with sensors that work to move towards the sun's energy in a variety of ways. It is characterized by the absence of power outages due to the presence of electrical source meters. These systems improve energy efficiency, reduce costs and improve process performance.
SCADA is used to control multiple power systems by monitoring and analyzing data from various sources such as electrical networks and connected devices. SCADA allows operators to have a comprehensive view of the HMI system and control it from one place, improving process efficiency and making quick, accurate decisions.

- **Problem definition**
  - Difficulties in stereoscopic work
  - Programming difficulties
  - Screen sizes and HMI
- **The main objectives of the graduation project**

- Continuous operation of electrical current through various energy sources.
- Providing a greater amount of electrical energy and protecting the environment from harmful emissions.
- The SCADA monitoring system via HMI is used remotely.
- Knowing the problem with the panel or battery, even if there are a thousand panels and batteries, and determining the location of the defect.
- Track the sun via LDR sensors to benefit as much as possible from solar energy.

- **Results**

- ❖ Sustainable energy industry
- ❖ Monitoring system to facilitate maintenance and cost.
- ❖ Producing the largest amount of solar energy.
- ❖ Manufacturing industries.

- **Conclusions and recommendations (in short)**

- ❖ Using Arduino and Raspberry Pi based systems allows you to achieve the automation control and monitoring required in your project.
- ❖ Each system can be used depending on the project requirements and desired complexity.
- ❖ Compatibility and communication between the Arduino and Raspberry Pi must be taken into account to ensure smooth and efficient performance.
- ❖ AI can be used to analyze data and further improve system efficiency.

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Acknowledgment

Example

Before and above all, we would like to record our endless thanks to **Allah** for everything he gives us.

We wish to express our deepest gratitude and appreciation to Assoc.Prof. Farouk Al-Fahidy for excellent guidance, kind encouragement, scientific advice, helpful supervision and good wishes instilled the strength in us to make this work possible.

Last but not least, we owe a great deal of gratitude, thanks and appreciation to all members of our families, for their kind support, help and encouragement.

Supervisor Certification

I certify that the preparation of this project entitled

…………………………………………………………………………………………,

prepared by ………………………………………………………………………

……………………………………………………………………………..

was mad under my supervision at ……………. department in partial fulfillment of the requirements of bachelor degree in ……………….

Supervisor Name

Signature

Date

Examiner Committee

Project Title: Multiple Power Management System Using SCADA

Supervisor

No	Name	Position	Signature
1			

Examiner Committee

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2			
3			

Department Head

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List of Abbreviations

Acronym	Definition
SCADA	Supervisory control and data acquisition
LDR	Light dependent resistors
ZMPT	MICRO PRECISION VOLTAGE TRANSFORMERS

Chapter 1

Introduction

1.1 Overview:

The SCADA With (Multiple Power Management System)

Multiple energy management systems using SCADA (intelligent central distribution control system) are a modern and innovative technology used to monitor and control energy consumption, monitor solar panels and batteries, determine which ones are faulty and do not generate energy, and are equipped with sensors that work to move towards the sun's energy in a variety of ways. It is characterized by the absence of power outages due to the presence of electrical source meters. These systems improve energy efficiency, reduce costs and improve process performance.

SCADA is used to control multiple power systems by monitoring and analyzing data from various sources such as electrical networks and connected devices. SCADA allows operators to have a comprehensive view of the HMI system and control it from one place, improving process efficiency and making quick, accurate decisions.

system is a comprehensive system used for the automatic monitoring and control of various industrial processes. The system consists of a set of devices and software that work together to collect data, monitor processes, and make appropriate decisions.

When a fault occurs in any of the sources, such as solar panels or batteries, the SCADA system can detect and report it. For example, if the solar panels experience a decrease in efficiency or a malfunction in some cells, the system's sensors will detect this change and send a warning signal to the control unit. The control unit can make decisions such as switching to an alternative power source or operating generators to compensate for the efficiency loss. Additionally, operators can use the HMI interface to monitor the status of sources and battery levels and make manual decisions, such as turning on or off a specific source.

The SCADA system also enables effective monitoring and management of energy consumption. Consumption data from various devices and equipment in a building or factory is collected and displayed on the HMI interface for operators. The operators can monitor consumption and analyze the data to take energy-saving measures and improve system efficiency.

By using SCADA systems in such environments, automated control of electricity generation, distribution, and consumption can be achieved, enhancing efficiency, sustainability, and ensuring 24/7 availability of energy.

1.2 Problem Statement:

1. Power outage: There may be a power outage coming from the public network, which requires switching the system to work on the power derived from the electric generator. It must be verified that the system responds correctly to transitions between power sources and to ensure continuity of operation.
2. Equipment malfunctions: Equipment and devices used in the multi-energy system, whether solar panels, transformers or generators, may malfunction. The condition of devices and equipment should be monitored and regular maintenance should be carried out to ensure that they are operating efficiently.
3. Decreased performance of solar panels: The performance of solar panels may be affected by factors such as pollution, dust buildup, or changes in solar illumination. The performance of solar panels must be monitored and cleaned regularly to maintain the highest level of electricity generation.
4. Problems with communication and networks: The SCADA system depends on effective communication between its components, including monitoring devices, transformers, generators, and solar panels. Networking or communications problems may occur that affect the system's ability to properly collect and analyze data.
5. Poor performance of the electric generator: Unstable performance or a decrease in the efficiency of the electric generator may occur, affecting its ability to provide the necessary electrical energy. The generator must be regularly maintained and its performance tested to ensure it operates efficiently when needed.

1.3 Project Objectives:

1. Continuous Power Supply: The project aims to provide uninterrupted and sustainable electricity supply by utilizing three different energy sources and advanced technologies such as solar energy and electrical generators.
2. Efficient Use of Solar Energy: The use of solar energy is a key aspect of the project, where a solar tracking sensor is installed to track the movement of the sun and ensure the maximum possible amount of electrical energy is obtained.
3. Effective Control and Monitoring: The project utilizes an advanced SCADA (Supervisory Control and Data Acquisition) system for control and monitoring, which connects to the Human-Machine Interface (HMI) to display all device-related information, status, and performance. This allows for efficient system monitoring and control.
4. Utilization of Artificial Intelligence: Artificial intelligence technology is used to collect and analyze device-related information, aiding in improving system efficiency and making smart decisions to enhance its performance.
5. Energy Conservation and Environmental Protection: The project is significant and unique in the field of clean and renewable energy generation, contributing to energy conservation and environmental protection by reducing harmful emissions.

6. Improvement of Essential Services: By providing continuous electricity supply, the project contributes to improving essential services related to electricity for local communities, such as hospitals, companies, and factories.
7. Sustainability and Sustainable Development: The project aims to achieve sustainability by providing sustainable electricity supply, improving system efficiency, and reducing operational and maintenance costs.
8. Significant Cost Reduction: By adopting solar energy technologies and improving system efficiency, the project can significantly reduce operational and maintenance costs in the long run. Additionally, advanced technologies such as artificial intelligence can be utilized to collect and analyze data, optimize energy usage efficiency, and achieve additional financial savings. The project's financial costs are very low compared to the benefits and savings that can be achieved in the long term.

1.4 Project motivations:

1. Meeting Vital Needs: The project aims to meet the vital needs of government entities, hospitals, companies, banks, factories, and any organization that requires uninterrupted electricity for their server operations. These needs are fulfilled by providing a reliable and continuous source of energy.
2. Providing Sustainable Energy: The project contributes to the provision of sustainable energy by utilizing solar power as the primary source of electricity generation. This reduces reliance on traditional energy sources and minimizes harmful emissions.
3. Achieving Reliability and Flexibility: Having three sources of electricity in the project is ideal for ensuring reliability and flexibility. In case of failure of one source, the other sources can continue to provide electricity consistently.
4. Reducing Energy Costs: By harnessing solar energy and using locally sourced electricity, the project helps to lower energy costs in the long run. The operational and maintenance costs of solar systems are typically lower compared to traditional energy costs.
5. Learning and Practical Application: The project offers an opportunity for students to apply the knowledge and skills they have acquired during their studies in engineering or sciences. They can learn about the design and installation of solar power systems and gain practical experience in working with them.
6. Innovation and Scientific Research: The project can serve as a platform for practical application of research and innovations in the field of renewable energy and energy systems. It enables exploration of new techniques and improvements in the efficiency of solar systems and energy utilization.

1.5 Project Methodology:

1. First Month: Research and information gathering were conducted from the internet and books regarding SCADA systems, their operation, and the positive aspects of implementing such a system. It was discovered that SCADA is a wide-ranging and versatile system with various

applications in different fields. The focus was on understanding the fundamental concepts and necessary information, emphasizing the needs and requirements specific to our country.
2. Second Month: The necessary electronic components for the project were purchased, and the datasheets of these components were studied to understand their usage, operation, and programming on controllers such as Raspberry Pi and Arduino.
3. Third Month: The design of the prototype was created using SolidWorks software, ensuring the required dimensions were met. The electrical circuit was also designed and simulated using Proteus software.
4. Fourth Month: Programming of the electronic components on Raspberry Pi and Arduino controllers was initiated, and the interfaces were programmed in the Human-Machine Interface (HMI) for user interaction.
5. Fifth Month: The system was built, and practical implementation of the system design was carried out by assembling and testing the components to ensure they performed according to the specified requirements.
6. Sixth Month: Refinement and modification of the system were performed based on the results and analysis obtained. The findings were utilized to make necessary improvements and modifications to enhance the system's performance.

1.6 Project Objectives:

Continuous operation of electrical current through various energy sources: solar energy, public electricity, and generator. The method of operation is automatic, and the energy conversion difference is estimated at 0.1 per second.

Providing a greater amount of electrical energy and protecting the environment from harmful emissions.

SCADA monitoring system is used via remote HMI.

Knowing the problem with the panel or battery, even if there are a thousand panels and batteries, and determining the location of the defect.

Tracking the sun via LDR sensors to benefit as much as possible from solar energy.

1.7 Project Methodology:

- *A simple mechanical system can provide smooth enough motion and enough power to move solar panels when two small 77RPM 12V 12W motors are used. For azimuth direction, the 1:6 gearbox is coupled to a 77rpm 12v DC motor and for steering limitation, a 10mm screw rod to a 77rpm 12vdc motor. This mechanical system provides slow, smooth movement and is powerful enough for a 2 x 20W solar panel.

- The materials for frame construction are 30mm*30mm square hollow steel, and 30mm iron flat bars. The build model and prototype shown in Figure 1. For the Raspberry Pi sensor board to be able to handle outdoor use and intense sunlight, a special case and filter are required. The enclosure made of Pertinax plate, since it is lightweight, durable and high temperature resistant, the upper part of the enclosure made of DIN 10 shade welder glass to protect the sensor from intense light and UV rays. A wide-angle lens applied to the Raspberry Pi's sensor increases its field of view. Figure 2. Showing the simple layout of the sensor housing.

Chapter 2

Background and Literature Review

2.1 Background:

SCADA is an acronym for Supervisory Control and Data Acquisition, and it is a system used in industrial control and monitoring processes. It is widely used in many industries, such as energy, oil and gas, water, manufacturing and transportation.

Here's some background on the SCADA system:

1. System Function: The SCADA system collects data from industrial processes with sensors, transducers and control equipment, then analyzes, processes and presents the data to human operators through an easy-to-use graphical user interface.
2. Main goal: SCADA aims to improve the efficiency of industrial processes by providing a comprehensive and effective view of the process and helping operators make the right decisions and intervene quickly when needed.
3. Main elements: The SCADA system usually consists of the following elements:
   - Central Control Unit (Master Terminal Unit): controls the data collection process and controls operations.
   Remote Terminal Units: collect data from field operations and send it to the central control unit.
   - Human-Machine Interface: Provides a graphical interface for operators to monitor and control operations.
   - Network: Communication networks are used to transfer data between field units and the central control unit.
4. Benefits: The SCADA system provides several benefits, such as increased productivity, improved product quality, reduced costs and downtime, and a safer working environment for operators.
5. Recent developments: As technology evolves, SCADA systems have come to rely on technologies such as cloud computing, artificial intelligence, and the Industrial Internet of Things (IIoT) to provide deeper analytics and greater performance improvements.

The SCADA system plays a crucial role in improving industrial processes and monitoring, and is an essential tool for comprehensive visibility and effective monitoring of industrial processes. You can find more information and details about the SCADA system by searching online or looking at books and specialized sources in this field.

2.2 Literature Review:

The SCADA system can be effectively used to monitor and control three energy sources: solar energy, grid electricity, and generator electricity. Here is an overview of how the SCADA system is applied in each:

1. Solar Energy:

A solar energy system consists of solar panels that convert solar energy into electrical energy. These solar panels can be connected to an SCADA system controller. The controller monitors the performance of the solar panels and generates reports on productivity and efficiency. The SCADA system can also be used to monitor and control the storage of energy generated by solar panels in subsequent batteries.

2. Grid electricity:

If the facility is connected to the public electricity grid, the SCADA system can be used to monitor and control electricity consumption. Smart meters can be connected to the SCADA system control unit to collect data about consumption and convert it into analyzable and displayable information. Operators can use the human operator interface to monitor consumption, analyze data and make energy saving decisions.

3. Electricity Generator:

If a generator is used as the power source, the Generator Control Module can be connected to the Escada system. The Escada system can monitor the generator's status and basic information such as fuel level, temperature and pressure. It can also record and analyze work and maintenance data and make alerts in case of any problem or deviation from optimal standards.

By using the Escada system for three different energy sources, facility monitoring and control can be centralized. This helps improve energy efficiency, save costs, and enhance safety and sustainability. The data collected from the three systems can be used to analyze performance and make smart decisions to optimize energy use and improve the overall efficiency of the facility.

Certainly! Here are some more details about using a SCADA system for monitoring and controlling three energy sources:

1. Data Visualization: SCADA systems provide powerful data visualization tools that allow operators to monitor the performance of the three energy sources. Through intuitive dashboards and graphical displays, operators can view real-time data, such as energy production from solar panels, electricity consumption from the grid, and generator status. These visualizations make it easy to identify trends, patterns, and anomalies, enabling operators to take timely actions.

2. Historical Data Analysis: SCADA systems store historical data, allowing operators to analyze past performance and trends. By analyzing historical data, operators can gain insights into energy usage patterns, identify inefficiencies, and optimize energy consumption. They can track the performance of each energy source over time, compare data from different periods, and make informed decisions to improve overall energy efficiency.

3. Remote Monitoring and Control: SCADA systems enable remote monitoring and control of the energy sources. Operators can access the SCADA system from anywhere, using web-based interfaces or mobile applications. This remote access allows them to monitor the energy sources, view real-time data, and control operations remotely. For example, they can remotely start or stop generators, adjust solar panel angles, or switch between grid and solar power sources.

4. Alarm and Event Management: SCADA systems provide alarm management capabilities to alert operators about critical events or abnormal conditions. Operators can set up alarms based on predefined thresholds or specific conditions. For instance, they can configure alarms to trigger when solar energy production drops below a certain level or when grid voltage exceeds safety limits. These alarms ensure that operators are promptly notified about any issues, enabling them to take immediate actions to prevent disruptions and maintain the stability of the energy system.

5. Energy Efficiency Optimization: SCADA systems can play a vital role in optimizing energy efficiency. By continuously monitoring energy production and consumption, operators can identify areas of improvement and implement energy-saving strategies. They can analyze energy usage patterns, identify energy-intensive processes or equipment, and optimize their

operation. This can lead to reduced energy waste, lower operational costs, and a more sustainable energy infrastructure.

6. Integration with Other Systems: SCADA systems can integrate with other systems and technologies to enhance functionality. For example, they can integrate with energy management systems, weather forecasting systems, or demand response systems. This integration allows for more advanced monitoring and control capabilities, such as adjusting energy generation based on weather conditions or participating in demand response programs to optimize energy usage during peak demand periods.

Overall, utilizing a SCADA system for monitoring and controlling multiple energy sources provides organizations with comprehensive visibility, improved operational efficiency, and the ability to make data-driven decisions for optimizing energy management. It helps ensure reliable and sustainable energy supply while reducing costs and minimizing environmental impact.

Chapter 3

Requirements Analysis and Modeling

3.1 Introduction:

SCADA is an acronym for Supervisory Control and Data Acquisition System, and it is a system used in many industrial and engineering applications to monitor and control various processes. In the context of the three energy sources that I mentioned, the Escada system can be used to monitor and control the generation of energy from multiple sources such as solar energy, electricity received from the grid, and a generator.

The SCADA system usually consists of several major components:

1. Sensors and measuring devices: used to measure information related to the energy produced from various sources, such as solar modules and current and voltage sensors.
2. Control units: They process sensor information and make regulatory and control decisions. These units can turn equipment on and off and adjust system settings based on the data received.
3. Communication unit: used to exchange data between the different parts of the system and the control center. Various communication media such as wired or wireless networks can be used to transmit data.
4. Control Center: It acts as an interface between the operators and the system. It allows operators to monitor and analyze data, make necessary decisions and, if necessary, intervene in operations.

Solar energy sources, electricity and electricity generator are connected to the SCADA system through special sensors and measuring devices to read production and performance information. This data is collected and sent to the control center using the appropriate communication module.

Using the SCADA system, operators can monitor the performance of each power source individually and analyze data on production and consumption. They can also adjust system settings and control the operation of various sources based on ambient conditions and power needs.

In addition, the SCADA system can be used to generate reports and statistics on the performance of various sources over the long term. Operators can monitor the efficiency of power generation, identify any problems or malfunctions in the system, and take measures to fix them.

In general, the Scada system enhances the efficiency of power generation from multiple sources and contributes to improving its sustainability. It allows data monitoring and precise control of power generation processes, which contributes to achieving better performance and reducing losses in the system.

Therefore, it can be said that the SCADA system plays an important role in integrating and controlling multiple energy sources such as solar energy, electricity, and electricity generators, and enhancing their efficiency and sustainability.

3.2 Raspberry Pi and Arduino in Electricity Generation and Process Control

3.2.1 Raspberry Pi:

It is a small-sized device used in building electronics and embedded systems. It is based on an ARM processor and runs on the Linux operating system. Raspberry Pi can be used to perform various functions such as control, monitoring, data storage, and communication with other devices. In your project, Raspberry Pi is used for device control and monitoring using SCADA and displaying information on an HMI interface.

Figure 3.1

In Figure 2.1, the Raspberry Pi controller is described as a small-sized computer based on microcomputing technology, known for its powerful capabilities and flexibility. It was initially developed as a tool for learning computer science and software development but has become popular and widely used in a variety of applications, ranging from home automation to industrial electronics projects.

1. Basic Specifications:

- Processor: The Raspberry Pi controller relies on various generations of ARM processing chips.
- Memory: It is available in different versions with varying memory capacities, such as 1GB, 2GB, or 4GB.
- Storage: It features a microSD card slot for storing the core system and data.
- Connectivity: It includes USB ports, an Ethernet port, Wi-Fi wireless capabilities, and Bluetooth.
- Input and Output: It has an HDMI port for connecting to displays, an audio port, and a GPIO (General-Purpose Input/Output) port.

2. Operating System:

- The Raspberry Pi can run the Raspbian operating system, which is based on Linux and specifically developed for the Raspberry Pi controller.
- In addition to Raspbian, other operating systems like Ubuntu and Windows 10 IoT Core can be installed and run on the Raspberry Pi.

3. Programming:

- The Raspberry Pi supports multiple programming languages such as Python, C, C++, Java, and more.
- A wide range of tools and libraries can be used for application and project development.

4. Applications:

- Home Automation: The Raspberry Pi can be used to control home devices like lighting, heating, and televisions.
- Electronics Projects: It can be employed in the development of various electronic projects such as robots, sensors, and measurement devices.
- Media Center: It can serve as a media center for playing multimedia content like videos and audio.

- Game Development: The Raspberry Pi can be used to develop simple games and fun gaming projects.

5. Compatible Hardware:

- There are numerous add-ons and accessories available for the Raspberry Pi, such as small screens, camera modules, sensors, motors, and more.
- These accessories can be connected to expand the capabilities and applications of the Raspberry Pi controller.

3.2.2 Arduino:

It is an open-source platform used for developing interactive electronic devices. Arduino consists of a programmable controller board with input/output ports. Arduino is used to connect and control various devices and sensors in your project. In your case, Arduino is used for controlling servo motors and sensing light using an LDR (Light Dependent Resistor).

While both Raspberry Pi and Arduino are used in implementing your project, they differ in the way they operate and the applications they can be used for. Raspberry Pi is a small computer capable of executing complex applications, networking, and storage systems. On the other hand, Arduino primarily focuses on direct control of devices and sensors. Additionally, Raspberry Pi operates on a comprehensive operating system like Linux, while Arduino uses a simple programmable control software.

Regarding the mentioned components in the systems used, such as the MG990 servo motor and LDR light sensor in Arduino, and the voltmeter, relays, HMI display, and database in Raspberry Pi, they are used for monitoring and controlling electricity generation and device operation automatically or manually.

In summary, our project utilizes SCADA technology and relies on Raspberry Pi and Arduino as control and monitoring systems. Raspberry Pi is used for advanced tasks such as device control, SCADA-based monitoring, and display on an HMI interface. Arduino is used for device control and environmental sensing, such as controlling servo motors and sensing light.

It can be observed that Raspberry Pi provides more complex capabilities and flexibility in control and network communication, while Arduino excels in its simplicity and specialization in direct device control.

Figure 3.2

In Figure 2.2, the Arduino Uno is described as a small-sized, open-source electronic development board designed to facilitate the development of interactive electronic devices and innovative projects. It is widely used in fields such as robotics, home automation, interactive electronics, sensing, and more. Here is a comprehensive explanation of the Arduino Uno controller:

1. Basic Specifications:

- Processor: The Arduino Uno utilizes an AVR microcontroller with a 16 MHz clock speed.
- Memory: It has 32 kilobytes of flash memory for program storage and 2 kilobytes of RAM for variables and data.
- Storage: It doesn't have built-in storage but can be connected to a microSD card to store data.
- Connectivity: It features a USB port for connection to a computer and two additional ports for external electronic devices.

2. Programming:

- The Arduino Uno is programmed using the simple C/C++ programming language, known as "Arduino Language."

- Arduino provides a dedicated programming editor that allows developers to easily write and upload programs to the controller.

3. Connections and Expandability:

- The Arduino Uno has GPIO (General-Purpose Input/Output) pins that enable the connection of various external electronic devices such as sensors, motors, displays, lighting devices, and more.

- A wide range of compatible components and electronic chips can be used with the Arduino Uno to expand its capabilities and create advanced projects.

4. Open-Source:

- The Arduino Uno relies on open-source code, meaning developers can access, customize, modify, and freely distribute the source code.

- This fosters flexibility and innovation in the use of the Arduino Uno controller.

5. Computer Connection:

- The Arduino Uno can be connected to a computer using the included USB cable. This connection is used to upload programs to the controller and communicate with it.

6. Compatibility:

- The Arduino Uno is compatible with a wide range of electronic components and external electronic chips, allowing developers to expand its capabilities and connect it to different devices.

Chapter 4

Project Design

4.1 Introduction

The SCADA is a process control system that qualifies a site operator to observe and control processes that are distributed between different distant sites. So, we can eliminate the need for service personnel to visit each site for inspection, data collection or make adjustments. Result of elimination is to save time and money. In addition, we can find SCADA system in many of industries such as electric distribution systems, facility security alarms, and food processing researchers could monitor and control ahybrid power system by Web-SCADA.

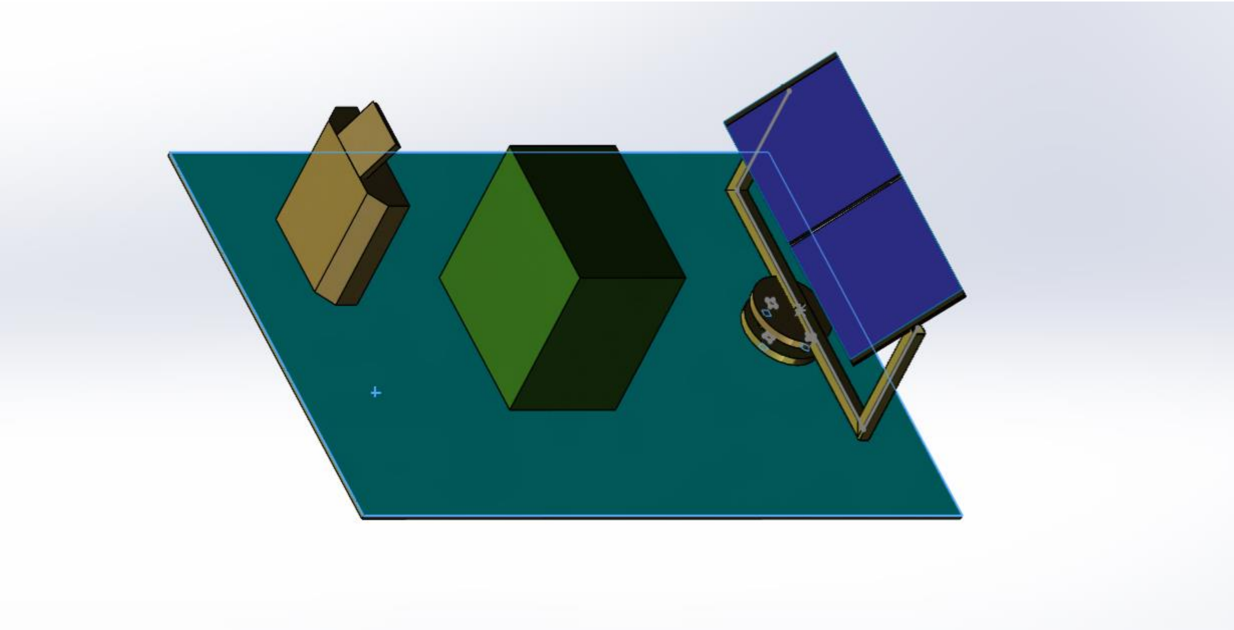


Figure 4.1

- **<u>Data sheet:</u>**

1.Raspberry Pi:

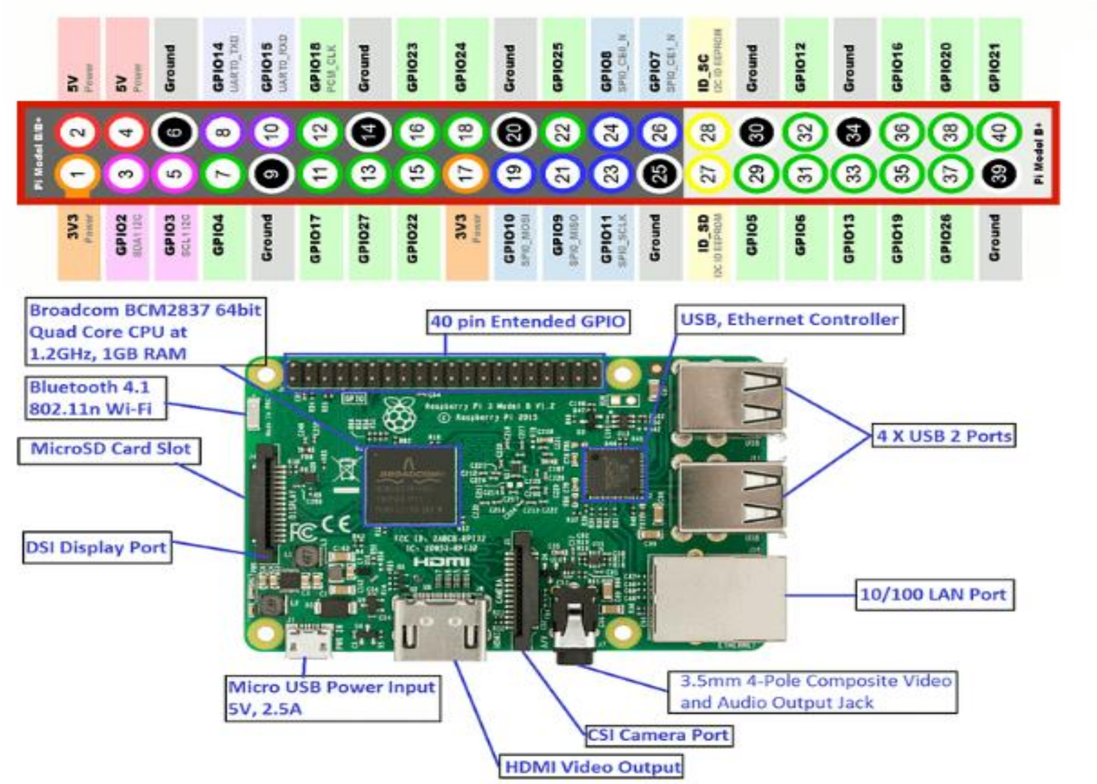


Figure 4.2

1.1 Introduction

The Raspberry Pi Compute Module 3+ (CM3+) is a range of DDR2-SODIMM-mechanically-compatible System on Modules (SoMs) containing processor, memory, eMMC Flash (on non-Lite variants) and supporting power circuitry. These modules allow a designer to leverage the Raspberry Pi hardware and software stack in their own custom systems and form factors. In addition these modules have extra IO interfaces over and above what is available on the Raspberry Pi model A/B boards, opening up more options for the designer.

The CM3+ contains a BCM2837B0 processor (as used on the Raspberry Pi 3B+), 1Gbyte LPDDR2 RAM and eMMC Flash. The CM3+ is currently available in 4 variants, CM3+/8GB, CM3+/16GB, CM3+/32GB and CM3+ Lite, which have 8, 16 and 32 Gigabytes of eMMC Flash, or no eMMC Flash, respectively.
The CM3+ Lite product is the same as CM3+ except the eMMC Flash is not fitted, and the SD/eMMC interface pins are available for the user to connect their own SD/eMMC device.
Note that the CM3+ is electrically identical and, with the exception of higher CPU z-height, physically identical to the legacy CM3 products.
CM3+ modules require a software/firmware image dated November 2018 or newer to function correctly.

1.2 Software

- ARMv8 Instruction Set
- Mature and stable Linux software stack
  - –Latest Linux Kernel support
  - –Many drivers upstreamed
  - –Stable and well supported userland
  - –Full availability of GPU functions using standard APIs

3.Block Diagram

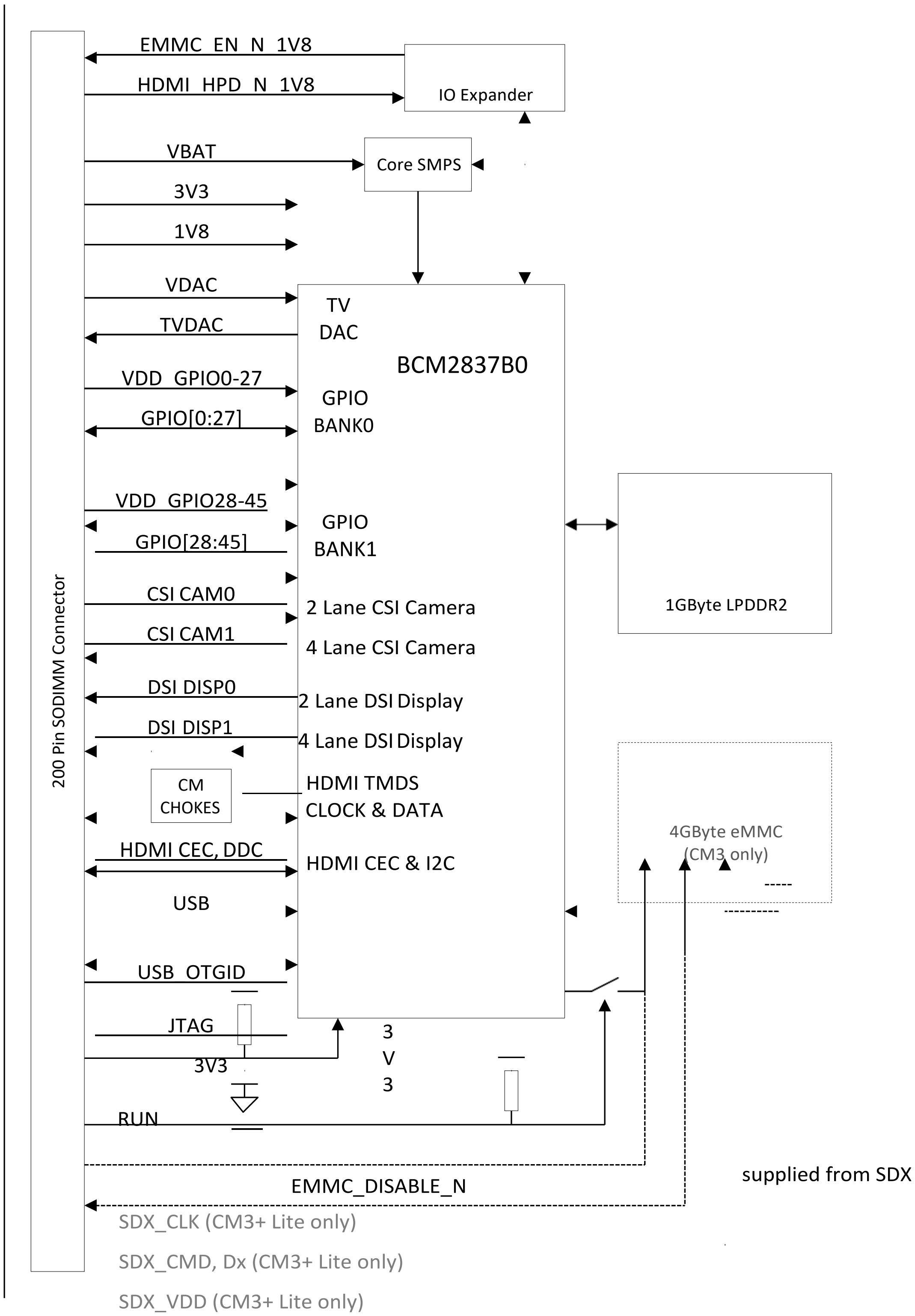


Figure 4.3 :
CM3+Block Diagram

4.Pin Assignments

CM3+	CM3+ Lite	PIN		PIN	CM3+	CM3+ Lite
GND		1		2	EMMC_DISABLE_N	
GPIO0		3		4	NC	SDX_VDD
GPIO1		5		6	NC	SDX_VDD
GND		7		8	GND	
GPIO2		9		10	NC	SDX_CLK
GPIO3		11		12	NC	SDX_CMD
GND		13		14	GND	
GPIO4		15		16	NC	SDX_D0
GPIO5		17		18	NC	SDX_D1
GND		19		20	GND	
GPIO6		21		22	NC	SDX_D2
GPIO7		23		24	NC	SDX_D3
GND		25		26	GND	
GPIO8		27		28	GPIO28	
GPIO9		29		30	GPIO29	
GND		31		32	GND	
GPIO10		33		34	GPIO30	
GPIO11		35		36	GPIO31	
GND		37		38	GND	
GPIO0-27_VDD		39		40	GPIO0-27_VDD	
			KEY			
GPIO28-45_VDD		41		42	GPIO28-45_VDD	
GND		43		44	GND	
GPIO12		45		46	GPIO32	
GPIO13		47		48	GPIO33	
GND		49		50	GND	
GPIO14		51		52	GPIO34	
GPIO15		53		54	GPIO35	
GND		55		56	GND	
GPIO16		57		58	GPIO36	
GPIO17		59		60	GPIO37	
GND		61		62	GND	
GPIO18		63		64	GPIO38	
GPIO19		65		66	GPIO39	
GND		67		68	GND	
GPIO20		69		70	GPIO40	
GPIO21		71		72	GPIO41	
GND		73		74	GND	
GPIO22		75		76	GPIO42	
GPIO23		77		78	GPIO43	
GND		79		80	GND	
GPIO24		81		82	GPIO44	
GPIO25		83		84	GPIO45	
GND		85		86	GND	
GPIO26		87		88	HDMI_HPD_N_1V8	
GPIO27		89		90	EMMC_EN_N_1V8	
GND		91		92	GND	
DSI0_DN1		93		94	DSI1_DP0	
DSI0_DP1		95		96	DSI1_DN0	
GND		97		98	GND	
DSI0_DN0		99		100	DSI1_CP	
DSI0_DP0		101		102	DSI1_CN	
GND		103		104	GND	
DSI0_CN		105		106	DSI1_DP3	
DSI0_CP		107		108	DSI1_DN3	
GND		109		110	GND	
HDMI_CLK_N		111		112	DSI1_DP2	
HDMI_CLK_P		113		114	DSI1_DN2	
GND		115		116	GND	
HDMI_D0_N		117		118	DSI1_DP1	
HDMI_D0_P		119		120	DSI1_DN1	
GND		121		122	GND	
HDMI_D1_N		123		124	NC	
HDMI_D1_P		125		126	NC	
GND		127		128	NC	
HDMI_D2_N		129		130	NC	
HDMI_D2_P		131		132	NC	
GND		133		134	GND	
CAM1_DP3		135		136	CAM0_DP0	
CAM1_DN3		137		138	CAM0_DN0	
GND		139		140	GND	
CAM1_DP2		141		142	CAM0_CP	
CAM1_DN2		143		144	CAM0_CN	
GND		145		146	GND	
CAM1_CP		147		148	CAM0_DP1	
CAM1_CN		149		150	CAM0_DN1	
GND		151		152	GND	
CAM1_DP1		153		154	NC	
CAM1_DN1		155		156	NC	
GND		157		158	NC	
CAM1_DP0		159		160	NC	
CAM1_DN0		161		162	NC	
GND		163		164	GND	
USB_DP		165		166	TVDAC	
USB_DM		167		168	USB_OTGID	
GND		169		170	GND	
HDMI_CEC		171		172	VC_TRST_N	
HDMI_SDA		173		174	VC_TDI	
HDMI_SCL		175		176	VC_TMS	
RUN		177		178	VC_TDO	
DD_CORE (DO NOT CONNECT		179		180	VC_TCK	
GND		181		182	GND	
1V8		183		184	1V8	
1V8		185		186	1V8	
GND		187		188	GND	
VDAC		189		190	VDAC	
3V3		191		192	3V3	
3V3		193		194	3V3	
GND		195		196	GND	
VBAT		197		198	VBAT	
VBAT		199		200	VBAT	

Table 1: Compute Module 3+ SODIMM Connector Pinout

5.Electrical Specifi

Caution! Stresses above those listed in Table may cause permanent damage to the device. This is a stress rating only; functional operation of the device under these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Minimum	Maximum	Unit
VBAT	Core SMPS Supply	-0.5	6.0	V
3V3	3V3 Supply Voltage	-0.5	4.10	V
1V8	1V8 Supply Voltage	-0.5	2.10	V
VDAC	TV DAC Supply	-0.5	4.10	V
GPIO0-27 VDD	GPIO0-27 I/O Supply Voltage	-0.5	4.10	V
GPIO28-45 VDD	GPIO28-45 I/O Supply Voltage	-0.5	4.10	V
SDX VDD	Primary SD/eMMC Supply Voltage	-0.5	4.10	V

Table 2: Absolute Maximum Ratings

6.Power Supplies

The Compute Module 3+ has six separate supplies that must be present and powered at all times; you cannot leave any of them unpowered, even if a specific interface or GPIO bank is unused. The six supplies are as follows:

1. VBAT is used to power the BCM2837 processor core.

It feeds the SMPS that generates the chip core voltage.

2. 3V3 powers various BCM2837 PHYs, IO and the eMMC Flash.
3. 1V8 powers various BCM2837 PHYs, IO and SDRAM.
4. VDAC powers the composite (TV-out) DAC.
5. GPIO0-27 VREF powers the GPIO 0-27 IO bank.
6. GPIO28-45 VREF powers the GPIO 28-45 IO bank.

Supply	**Descripion**	**Minimum**	**Typical**	**Maximum**	**Unit**
VBAT	Core SMPS Supply	2.5	-	5.0 + 5%	V
3V3	3V3 Supply Voltage	3.3 - 5%	3.3	3.3 + 5%	V
1V8	1V8 Supply Voltage	1.8 - 5%	1.8	1.8 + 5%	V
VDAC	TV DAC Supply[a]	2.5 - 5%	2.8	3.3 + 5%	V
GPIO0-27 VDD	GPIO0-27 I/O Supply Voltage	1.8 - 5%	-	3.3 + 5%	V
GPIO28-45 VDD	GPIO28-45 I/O Supply Voltage	1.8 - 5%	-	3.3 + 5%	
V					
SDX VDD	Primary SD/eMMC Supply Voltage	1.8 - 5%	-	3.3 + 5%	V

[a] Requires a clean 2.5-2.8V supply if TV DAC is used, else connect to 3V3

Table 3: Power Supply Operating Ranges

6.1 Supply Sequencing

Supplies should be staggered so that the highest voltage comes up first, then the remaining voltages in descending order. This is to avoid forward biasing internal (on-chip) diodes between supplies, and causing latch-up. Alternatively supplies can be synchronised to come up at exactly the same time as long as at no point a lower voltage supply rail voltage exceeds a higher voltage supply rail voltage.

6.2 Power Requirements

Exact power requirements will be heavily dependent upon the individual use case. If an on-chip subsys- tem is unused, it is usually in a low power state or completely turned off. For instance, if your application does not use 3D graphics then a large part of the core digital logic will never turn on and need power. This is also the case for camera and display interfaces, HDMI, USB interfaces, video encoders and decoders, and so on.

Powerchain design is critical for stable and reliable operation of the Compute Module 3+. We strongly recommend that designers spend time measuring and verifying power requirements for their particular use case and application, as well as paying careful attention to power supply sequencing and maximum supply voltage tolerance.

Table specifies the recommended minimum power supply outputs required to power the Compute Module 3+.

Supply	Minimum Requirement	Unit
VBAT (CM1)	2000[a]	mW
VBAT (CM3,3L)	3500[a]	mW
3V3	250	mA
1V8	250	mA
VDAC	25	mA
GPIO0-27 VDD	50[b]	mA
GPIO28-45 VDD	50[b]	mA
SDX VDD	50[b]	mA

[a]. Recommended minimum. Actual power drawn is very dependent on use-case
[b]. Each GPIO can supply up to 16mA, aggregate current per bank must not exceed

7. Peripherals

7.1 GPIO

BCM2837 has in total 54 GPIO lines in 3 separate voltage banks. All GPIO pins have at least two alternative functions within the SoC. When not used for the alternate peripheral function, each GPIO pin may be set as an input (optionally as an interrupt) or an output. The alternate functions are usually peripheral I/Os, and most peripherals appear twice to allow flexibility on the choice of I/O voltage.

GPIO bank2 is used on the module to connect to the eMMC device and for an on-board I2C bus (to talk to the core SMPS and control the special function pins). On CM3+ Lite most of bank2 is exposed to allow a user to connect their choice of SD card or eMMC device (if required).

Bank0 and 1 GPIOs are available for general use. GPIO0 to GPIO27 are bank0 and GPIO28-45 make up bank1. GPIO0-27 VDD is the power supply for bank0 and GPIO28-45 VDD is the power supply for bank1. SDX VDD is the supply for bank2 on CM3+ Lite. These supplies can be in the range 1.8V-3.3V and are not optional; each bank must be powered, even when none of the GPIOs for that bank are used.

All GPIOs except GPIO28, 29, 44 and 45 have weak in-pad pull-ups or pull-downs enabled when the device is powered on.

7.1.2 GPIO Alternate Functions

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
0	High	SDA0	SA5	PCLK	-	-	-
1	High	SCL0	SA4	DE	-	-	-
2	High	SDA1	SA3	LCD VSYNC	-	-	-
3	High	SCL1	SA2	LCD HSYNC	-	-	-
4	High	GPCLK0	SA1	DPI D0	-	-	ARM TDI
5	High	GPCLK1	SA0	DPI D1	-	-	ARM TDO
6	High	GPCLK2	SOE N	DPI D2	-	-	ARM RTCK
7	High	SPI0 CE1 N	SWE N	DPI D3	-	-	-
8	High	SPI0 CE0 N	SD0	DPI D4	-	-	-
9	Low	SPI0 MISO	SD1	DPI D5	-	-	-
10	Low	SPI0 MOSI	SD2	DPI D6	-	-	-
11	Low	SPI0 SCLK	SD3	DPI D7	-	-	-
12	Low	PWM0	SD4	DPI D8	-	-	ARM TMS
13	Low	PWM1	SD5	DPI D9	-	-	ARM TCK
14	Low	TXD0	SD6	DPI D10	-	-	TXD1
15	Low	RXD0	SD7	DPI D11	-	-	RXD1
16	Low	FL0	SD8	DPI D12	CTS0	SPI1 CE2 N	CTS1
17	Low	FL1	SD9	DPI D13	RTS0	SPI1 CE1 N	RTS1
18	Low	PCM CLK	SD10	DPI D14	-	SPI1 CE0 N	PWM0
19	Low	PCM FS	SD11	DPI D15	-	SPI1 MISO	PWM1
20	Low	PCM DIN	SD12	DPI D16	-	SPI1 MOSI	GPCLK0
21	Low	PCM DOUT	SD13	DPI D17	-	SPI1 SCLK	GPCLK1
22	Low	SD0 CLK	SD14	DPI D18	SD1 CLK	ARM TRST	-
23	Low	SD0 CMD	SD15	DPI D19	SD1 CMD	ARM RTCK	-
24	Low	SD0 DAT0	SD16	DPI D20	SD1 DAT0	ARM TDO	-
25	Low	SD0 DAT1	SD17	DPI D21	SD1 DAT1	ARM TCK	-
26	Low	SD0 DAT2	TE0	DPI D22	SD1 DAT2	ARM TDI	-
27	Low	SD0 DAT3	TE1	DPI D23	SD1 DAT3	ARM TMS	-

Table 5: GPIO Bank0 Alternate Functions

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
28	None	SDA0	SA5	PCM CLK	FL0	-	-
29	None	SCL0	SA4	PCM FS	FL1	-	-
30	Low	TE0	SA3	PCM DIN	CTS0	-	CTS1
31	Low	FL0	SA2	PCM DOUT	RTS0	-	RTS1
32	Low	GPCLK0	SA1	RING OCLK	TXD0	-	TXD1
33	Low	FL1	SA0	TE1	RXD0	-	RXD1
34	High	GPCLK0	SOE N	TE2	SD1 CLK	-	-
35	High	SPI0 CE1 N	SWE N	-	SD1 CMD	-	-
36	High	SPI0 CE0 N	SD0	TXD0	SD1 DAT0	-	-
37	Low	SPI0 MISO	SD1	RXD0	SD1 DAT1	-	-
38	Low	SPI0 MOSI	SD2	RTS0	SD1 DAT2	-	-
39	Low	SPI0 SCLK	SD3	CTS0	SD1 DAT3	-	-
40	Low	PWM0	SD4	-	SD1 DAT4	SPI2 MISO	TXD1
41	Low	PWM1	SD5	TE0	SD1 DAT5	SPI2 MOSI	RXD1
42	Low	GPCLK1	SD6	TE1	SD1 DAT6	SPI2 SCLK	RTS1
43	Low	GPCLK2	SD7	TE2	SD1 DAT7	SPI2 CE0 N	CTS1
44	None	GPCLK1	SDA0	SDA1	TE0	SPI2 CE1 N	-
45	None	PWM1	SCL0	SCL1	TE1	SPI2 CE2 N	-

Table 6: GPIO Bank1 Alternate Functions

Table 5 and Table 6 detail the default pin pull state and available alternate GPIO functions. Most of these alternate peripheral functions are described in detail in the Broadcom Peripherals Specification document and have Linux drivers available.

7.1.2 Secondary Memory Interface (SMI)

The SMI peripheral is an asynchronous NAND type bus supporting Intel mode80 type transfers at 8 or 16 bit widths and available in the ALT1 positions on GPIO banks 0 and 1 It is not publicly documented in the Broadcom Peripherals Specification but a Linux driver is available in the Raspberry Pi Github Linux repository (bcm2835 smi.c in linux/drivers/misc).

7.1.3 Display Parallel Interface (DPI)

A standard parallel RGB (DPI) interface is available on bank 0 GPIOs. This up-to-24-bit parallel inter- face can support a secondary display. Again this interface is not documented in the Broadcom Peripher- als Specification but documentation can be found here.

7.1.4 SD/SDIO Interface

The BCM283x supports two SD card interfaces, SD0 and SD1.
The first (SD0) is a proprietary Broadcom controller that does not support SDIO and is the primary interface used to boot and talk to the eMMC or SDX x signals.
The second interface (SD1) is standards compliant and can interface to SD, SDIO and eMMC devices; for example on a Raspberry Pi 3 B+ it is used to talk to the on-board CYW43455 WiFi device in SDIO mode.
Both interfaces can support speeds up to 50MHz single ended (SD High Speed Mode).

7.2 CSI (MIPI Serial Camera)

Currently the CSI interface is not openly documented and only CSI camera sensors supported by the official Raspberry Pi firmware will work with this interface. Supported sensors are the OmniVision OV5647 and Sony IMX219.

It is recommended to attach other cameras via USB.

7.3 DSI (MIPI Serial Display)

Currently the DSI interface is not openly documented and only DSI displays supported by the official Raspberry Pi firmware will work with this interface.

Displays can also be added via the parallel DPI interface which is available as a GPIO alternate function

7.4 USB

The BCM2837 USB port is On-The-Go (OTG) capable. If using either as a fixed slave or fixed master, please tie the USB OTGID pin to ground.

The USB port (Pins USB DP and USB DM) must be routed as 90 ohm differential PCB traces.

Note that the port is capable of being used as a true OTG port however there is no official documentation. Some users have had success making this work.

7.5 HDMI

BCM283x supports HDMI V1.3a.

It is recommended that users follow a similar arrangement to the Compute Module IO Board circuitry for HDMI output.

The HDMI CK P/N (clock) and D0-D2 P/N (data) pins must each be routed as matched length 100 ohm differential PCB traces. It is also important to make sure that each differential pair is closely phase matched. Finally, keep HDMI traces well away from other noise sources and as short as possible. Failure to observe these design rules is likely to result in EMC failure.

7.6 Composite (TV Out)

The TVDAC pin can be used to output composite video (PAL or NTSC). Please route this signal away from noise sources and use a 75 ohm PCB trace.

Note that the TV DAC is powered from the VDAC supply which must be a clean supply of 2.5-2.8V. It is recommended users generate this supply from 3V3 using a low noise LDO.

If the TVDAC output is not used VDAC can be connected to 3V3, but it must be powered even if the TV-out functionality is unused.

8. Thermals

The BCM2837 SoC employs DVFS (Dynamic Voltage and Frequency Scaling) on the core voltage. When the processor is idle (low CPU utilisation), it will reduce the core frequency and voltage to reduce current draw and heat output. When the core utilisation exceeds a certain threshold the core votlage is increased and the core frequency is boosted to the maximum working frerquency of 1.2GHz. The voltage and frequency are throttled back when the CPU load reduces back to an 'idle' level OR when the silicon temperature as mesured by the on-chip temperature sensor exceeds 80C (thermal throttling).

A designer must pay careful attention to the thermal design of products using the CM3+ so that performance is not artificially curtailed due to the processor thermal throttling, as the Quad ARM complex in the BCM2837 can generate significant heat output under load.

8.1 Temperature Range

The operating temperature range of the module is set by the lowest maximum and highest minimum of any of the components used.

The eMMC and LPDDR2 have the narrowest range, these are rated for -25 to +80 degrees Celsius. Therefore the nominal range for the CM3+ and CM3+ Lite is -25C to +80C.

However, this range is the maximum for the silicon die; therefore, users would have to take into account the heat generated when in use and make sure this does not cause the temperature to exceed 80 degrees Celsius.

9. Availability

Raspberry Pi guarantee availability of CM3+ and CM3+ Lite until at least January 2026.

10. Support

For support, please see the hardware documentation section of the Raspberry Pi website and post ques- tions to the Raspberry Pi forum.

2. Arduino Uno

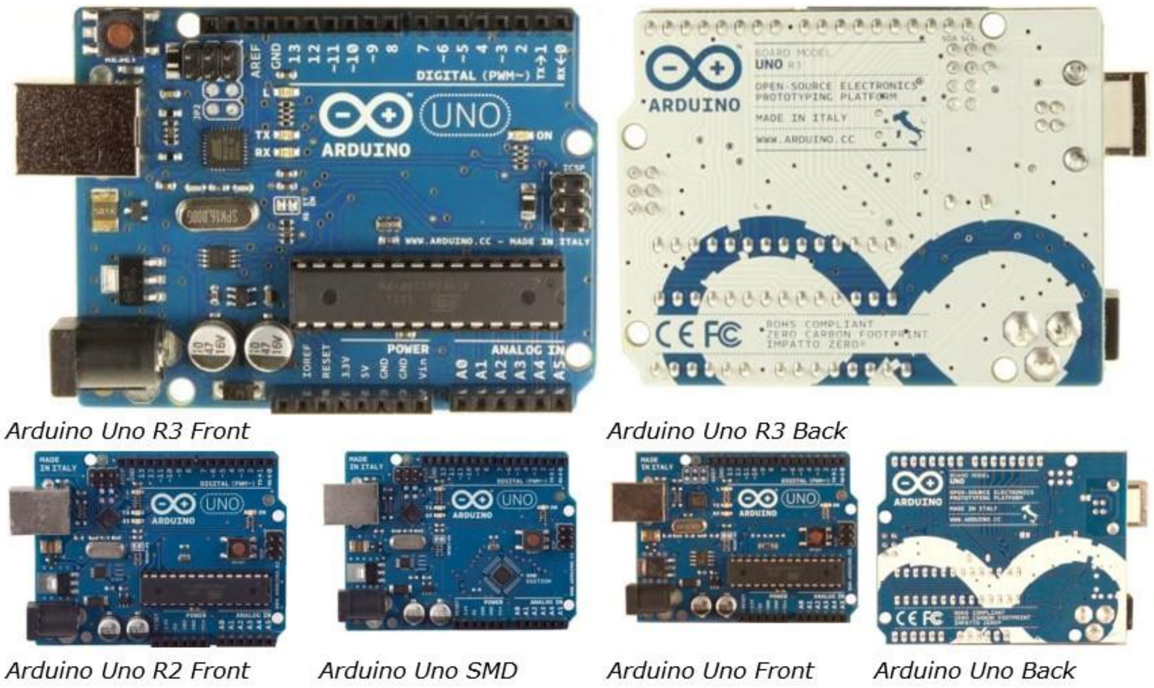


Figure 4.4

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the

Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller ATmega328

Operating Voltage 5V Input Voltage (recommended) 7-12V

Input Voltage (limits) 6-20V

Digital I/O Pins 14 (of which 6 provide PWM output)

Analog Input Pins 6

DC Current per I/O Pin 40 mA DC Current for 3.3V Pin 50 mA

Flash Memory 32 KB (ATmega328) of which 0.5 KB used by bootloader SRAM 2 KB (ATmega328)

EEPROM 1 KB (ATmega328)

Clock Speed 16 MHz

Schematic & Reference Design

EAGLE files: arduino-uno-Rev3-reference-design.zip (NOTE: works with Eagle 6.0 and newer) Schematic: arduino-uno-Rev3-schematic.pdf

Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V.This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin

of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.

- 3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND. Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode, digitalWrite, and digitalRead functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- AREF. Reference voltage for the analog inputs. Used with analogReference.

• Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and ATmega328 ports. The mapping for the Atmega8, 168, and 328 is identical.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A Software Serial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available . The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half- second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

Biosensors and Electronic parts:

MG995 High Speed

Metal Gear Dual Ball Bearing Servo

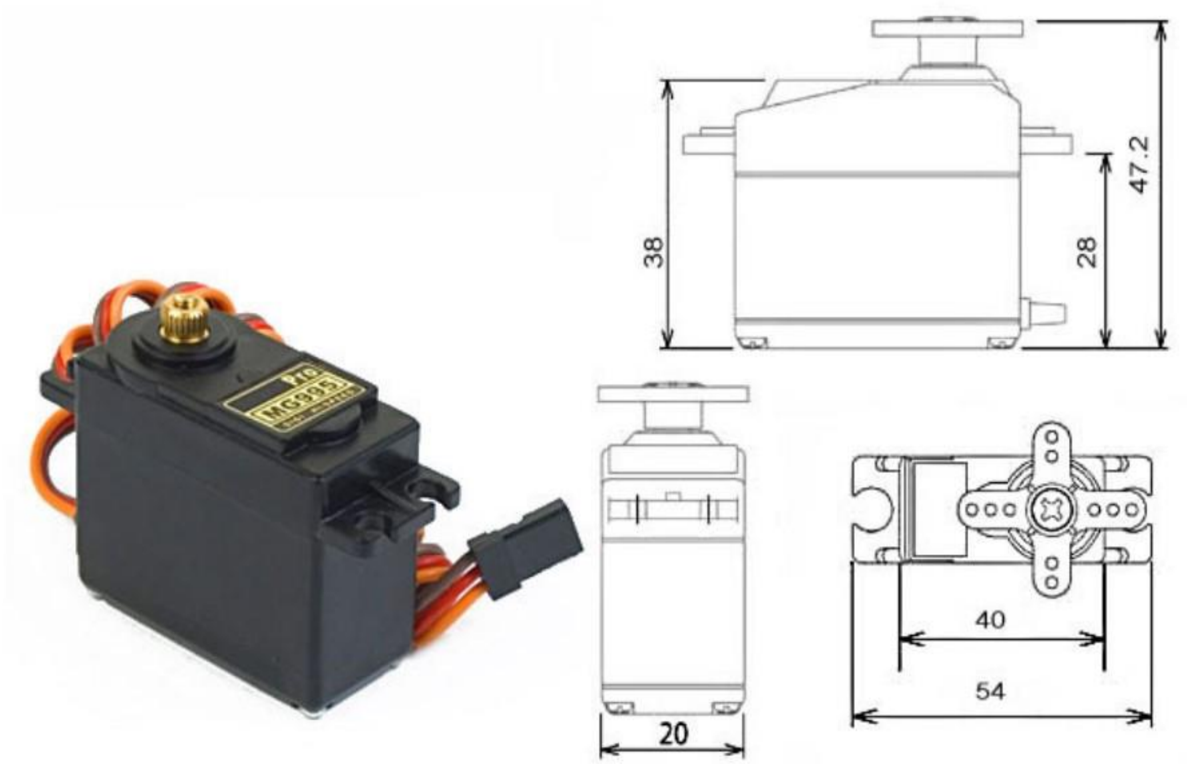


Figure 4.5

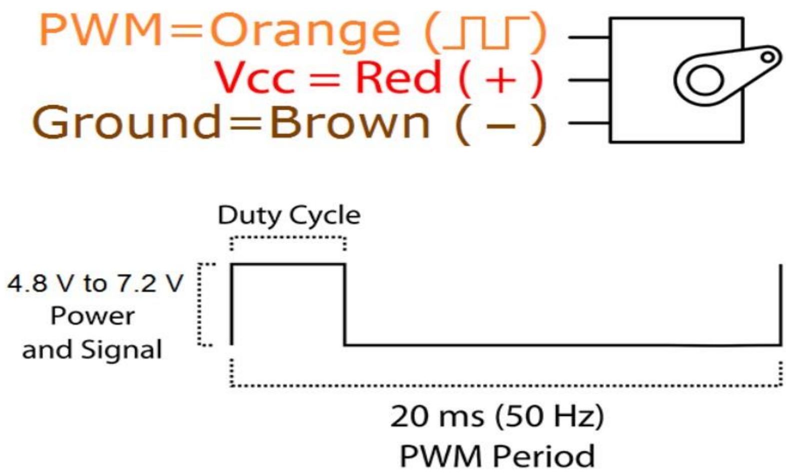
The unit comes complete with 30cm wire and 3 pin **"**S**"** type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec**.**

This high-speed standard servo can rotate approximately 120 degrees (60 in each direction).

You can use any servo code, hardware or library to control these servos, so it's great for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. The MG995 Metal Gear Servo also comes with a selection of arms and hardware to get you set up nice and fast!

- Specifications**:**

• Weight: 55 g**.**
• Dimension: 40.7 x 19.7 x 42.9 mm approx.
• Stall torque: 8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)**.**
• Operating speed: 0.2 s/60º (4.8 V), 0.16 s/60º (6 V)**.**
• Operating voltage: 4.8 V a 7.2 V**.**
• Dead band width: 5 μs**.**
• Stable and shock proof double ball bearing design**.**
• Temperature range: 0 ºC – 55 ºC**.**



*Light dependent resistors:

Figure 4.6

Two cadmium sulphide (cdS) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light inten- sity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm sys- tems.

Guide to source illuminations

Light source Illumination (Lux)

Moonlight.........................0.1

60W bulb at 1m................50

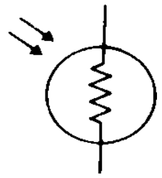
1W MES bulb at 0.1m................100

Fluorescent lighting................50

Bright sunlight................30,000

Light dependent resistors have a particular property in that they

Circuit symbol



remember the lighting conditions in which they have been stored. This memory effect can be minimised by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values.

NORP12 (RS stock no. 651-507)

Absolute maximum ratings

Voltage, ac or dc peak......................320V

Curren......................75mA

Power dissipation at 30°C......................250mW

Operating temperature range......................-60°C to +75°C

Electrical characteristics

TA = 25°C. 2854°K tungsten light source

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	- -	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

Table 4-6: Electrical characteristics

1. Dark to 110% RL
2. To 10 × RL

RL = photocell resistance under given illumination.

Features

*	Wide spectral response

*	Low cost

*	Wide ambient temperature range

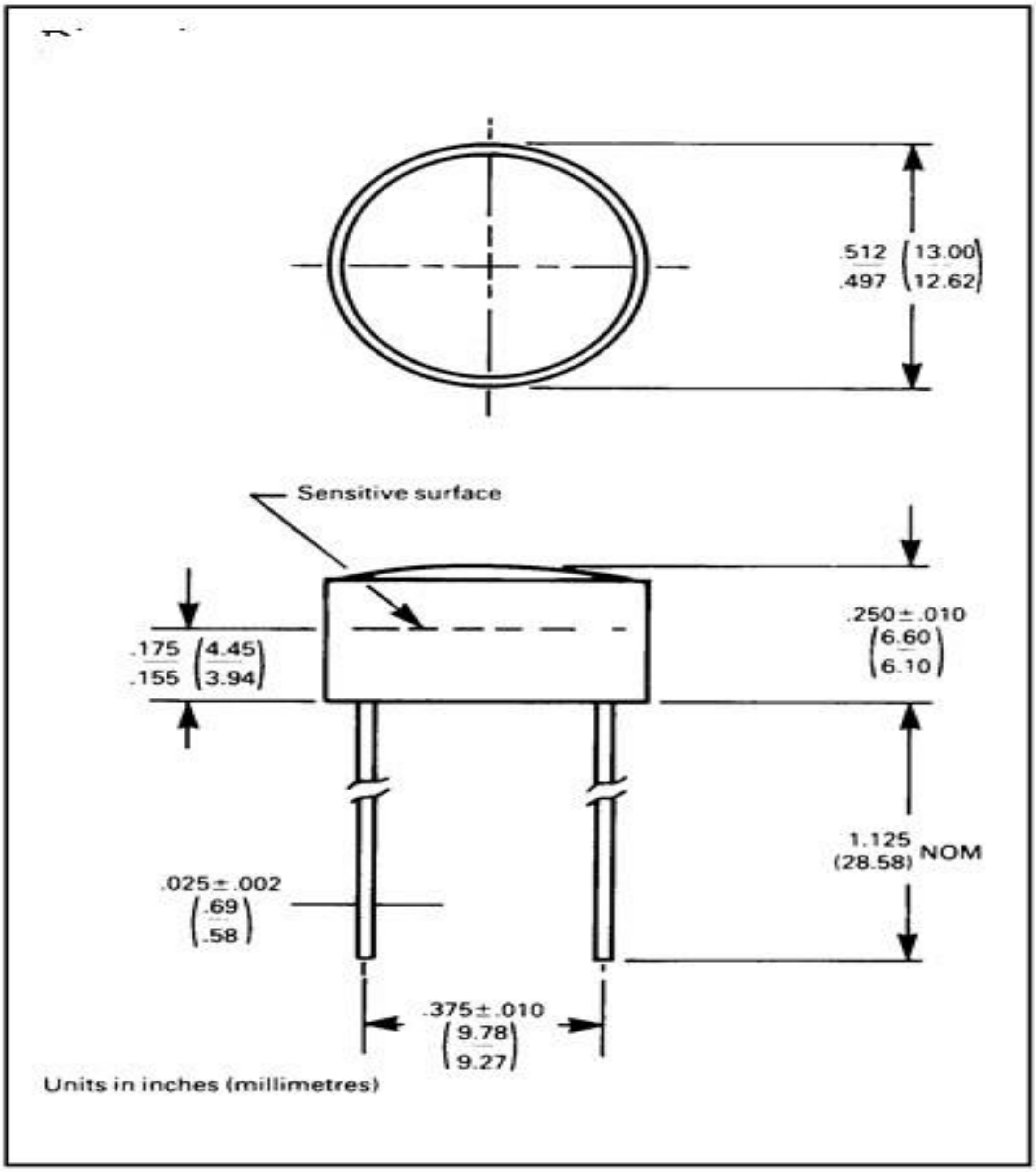


Figure 4.7

Series Voltage Regulators "LM78XX"

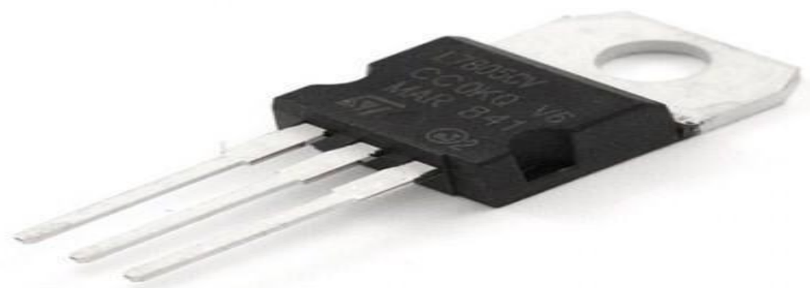


Figure 4.8

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumenta- tion, HiFi, and other solid state electronic equipment. Al- though designed primarily as fixed voltage regulators these devices can be used with external components to obtain ad- justable voltages and currents.

The LM78XX series is available in an aluminum TO-3 pack- age which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissi- pation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX se- ries of regulators easy to use and minimize the number of external components. It is not necessary to bypass the out- put, although this does improve transient response. Input by- passing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features

* Output current in excess of 1A
* Internal thermal overload protection
* No external components required
* Output transistor safe area protection
* Internal short circuit current limit
* Available in the aluminum TO-3 package

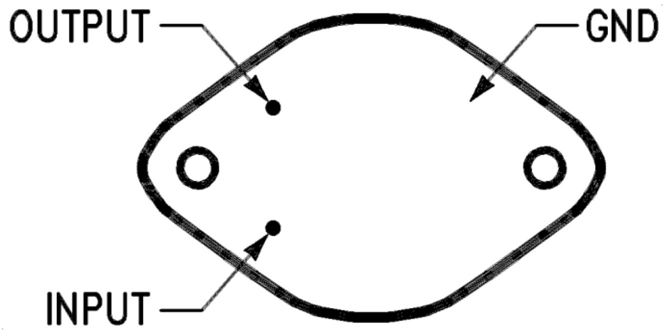
Voltage Range

LM7805C 5V

LM7812C 12V

LM7815C 15V

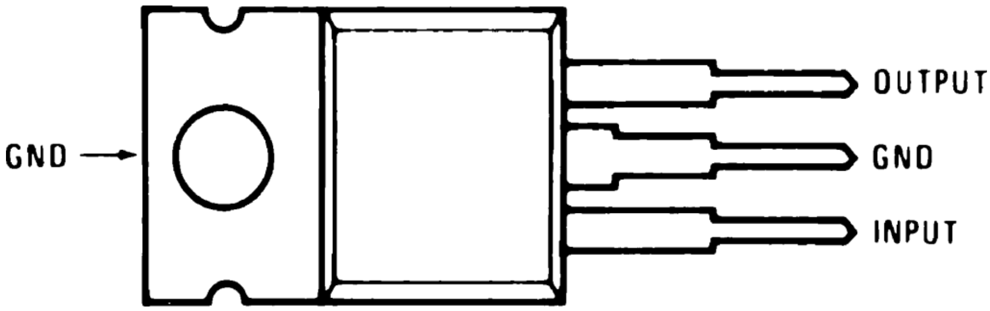
Metal Can Package TO-3 (K)
Aluminum



DS007746-2

Bottom View
Order Number LM7805CK,
LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package TO-220 (T)



DS007746-3

TOP View
Order Number LM7805CT, LM7812CT or LM7815CT
See NS Package Number T03B

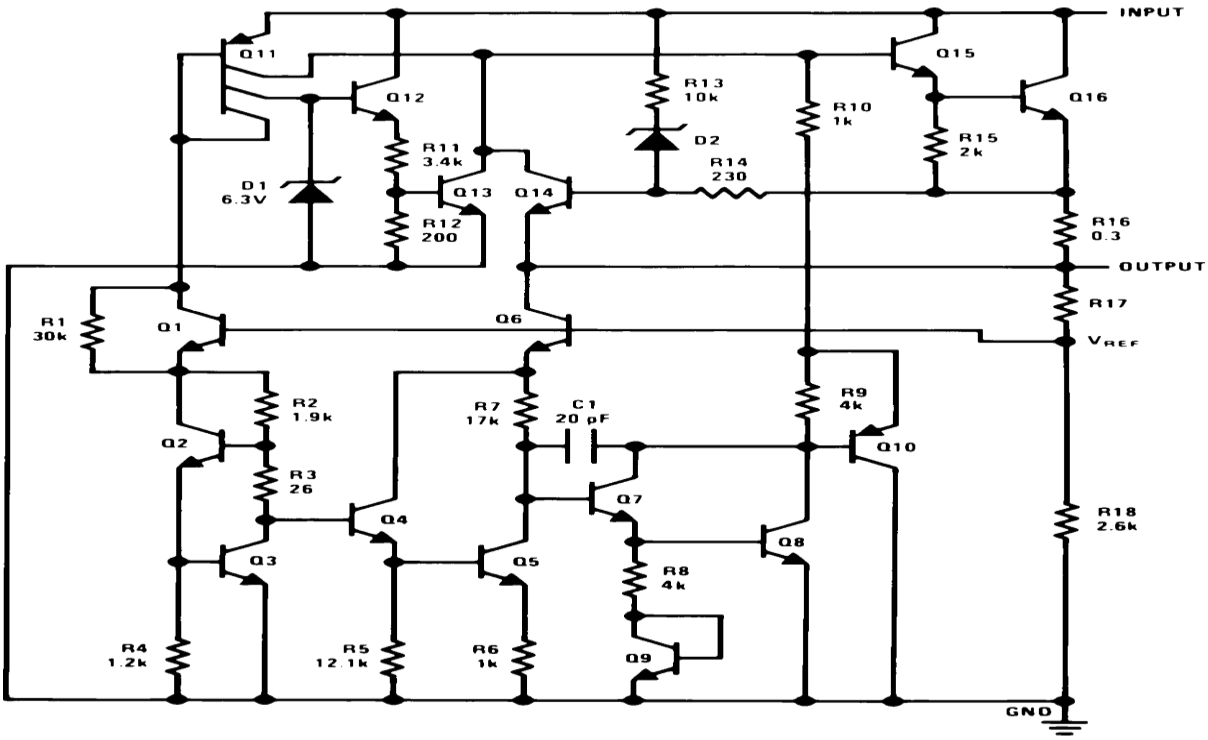


Figure 4.9

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage

(VO = 5V, 12V and 15V) 35V

Internal Power Dissipation (Note 1) Internally Limited Operating Temperature Range (TA) 0˚C to +70˚C

- Electrical Characteristics LM78XXC

0˚C ≤ TJ ≤ 125˚C unless otherwise noted.

Maximum Junction Temperature

(K Package) 150˚C

(T Package) 150˚C

Storage Temperature Range −65˚C to +150˚C

Lead Temperature (Soldering, 10 sec.)

TO-3 Package K 300˚C

TO-220 Package T 230˚C

Output Voltage				5V			12V			15V			Units
Input Voltage (unless otherwise noted)				10V			19V			23V			
Symbol	Parameter	Conditions		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_O	Output Voltage	Tj = 25˚C, 5 mA ≤ I_O ≤ 1A		4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V
		P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A		4.75		5.25	11.4		12.6	14.25		15.75	V
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}		(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			V
ΔV_O	Line Regulation	I_O = 500 mA	Tj = 25˚C ΔV_{IN}	3 5 0 (7 ≤ V_{IN} ≤ 25)			4 12 0 14.5 ≤ V_{IN} ≤ 30)			4 15 0 (17.5 ≤ V_{IN} ≤ 30)			mV V
			0˚C ≤ Tj ≤ +125˚C ΔV_{IN}	50 (8 ≤ V_{IN} ≤ 20)			120 (15 ≤ V_{IN} ≤ 27)			150 (18.5 ≤ V_{IN} ≤ 30)			mV V
		I_O ≤ 1A	Tj = 25˚C ΔV_{IN}	50 (7.5 ≤ V_{IN} ≤ 20)			120 (14.6 ≤ V_{IN} ≤ 27)			150 (17.7 ≤ V_{IN} ≤ 30)			mV V
			0˚C ≤ Tj ≤ +125˚C ΔV_{IN}	25 (8 ≤ V_{IN} ≤ 12)			60 (16 ≤ V_{IN} ≤ 22)			75 (20 ≤ V_{IN} ≤ 26)			mV V
ΔV_O	Load Regulation	Tj = 25˚C	5 mA ≤ I_O ≤ 1.5A		10	50		12	120		12	150	mV
			250 mA ≤ I_O ≤ 750 mA			25			60			75	mV
		5 mA ≤ I_O ≤ 1A, 0˚C ≤ Tj ≤ +125˚C				50			120			150	mV
I_Q	Quiescent Current	I_O ≤ 1A	Tj = 25˚C 0˚C ≤ Tj ≤ +125˚C			8 8.5			8 8.5			8 8.5	mA mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_O ≤ 1A				0.5			0.5			0.5	mA
		Tj = 25˚C, I_O ≤ 1A V_{MIN} ≤ V_{IN} ≤ V_{MAX}		1.0 (7.5 ≤ V_{IN} ≤ 20)			1.0 (14.8 ≤ V_{IN}≤ 27)			1.0 (17.9 ≤ V_{IN} ≤ 30)			mA V
		I_O ≤ 500 mA, 0˚C ≤ Tj ≤		1.0 (7 ≤ V_{IN} ≤ 25)			1.0 (14.5 ≤ V_{IN}≤			1			m

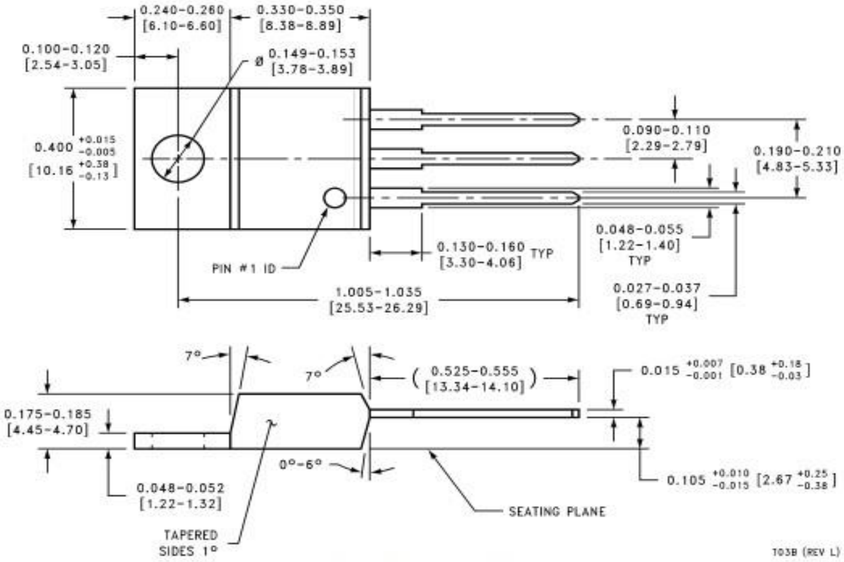
Electrical Characteristics LM78XXC (Note 2)

(Continued) 0˚C ≤ T_J ≤ 125˚C unless otherwise noted.

Output Voltage			5V			12V			15V			Units
Input Voltage (unless otherwise noted)			10V			19V			23V			
Symbol	Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
	Short-Circuit Current	Tj = 25˚C		2.1			1.5			1.2		A
	Peak Output Current	Tj = 25˚C		2.4			2.4			2.4		A
	Average TC of V_{OUT}	0˚C ≤ Tj ≤ +125˚C, I_O = 5 mA		0.6			1.5			1.8		mV/˚C
V_{IN}	Input Voltage Required to Maintain Line Regulation	Tj = 25˚C, I_O ≤ 1A		7.5		14.6			17.7			V
		+125˚C V_{MIN} ≤ V_{IN} ≤ V_{MAX}				30)			.0 (17.5 ≤ V_{IN} ≤ 30)			A V
V_N	Output Noise Voltage	T_A =25˚C, 10 Hz ≤ f ≤ 100 kHz		40			75			90		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz, I_O ≤ 1A, Tj = 25˚C or	62	80		55	72		54	70		dB
		f = 120 Hz, I_O ≤ 500 mA 0˚C ≤ Tj ≤ +125˚C	62			55			54			dB
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}	(8 ≤ V_{IN} ≤ 18)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)			V
R_O	Dropout Voltage	Tj = 25˚C, I_{OUT} = 1A		2.0			2.0			2.0		V
	Output Resistance	f = 1 kHz		8			18			19		mΩ

Tablo 4-7

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



TO-220 Package (T)
Order Number LM7805CT, LM7812CT or LM7815CT
NS Package Number T03B

Figure 4.10

- **CONDUCTIVE POLYMER**

Figure4.11

* High reliability, High voltage (to 80V).
* Low ESR, High ripple current.
* Long life of 4000 hours at 135°C.
* SMD type : Lead free reflow soldering condition at
 260°C peak complete correspondence.
* Compliant to the RoHS directive (2011/65/EU,(EU)2015/863).
* ESR after Endurance at -40°C.
* AEC-Q200 compliant. Please contact us for details.

- Specifications:

Item	Performance Characteristics
Category Temperature Range	– 55 to +135°C
Rated Voltage Range	16 to 80V
Rated Capacitance Range	12 to 1000μF
Capacitance Tolerance	± 20% at 120Hz, 20°C
Tangent of loss angle (tan δ)	Less than or equal to the specified value at 120Hz, 20°C
ESR (※1)	Less than or equal to the specified value at 100kHz, 20°C
Leakage Current (※2)	After 2 minutes' application of rated voltage, leakage current is not more than 0.03CV or 3(μA), whichever is greater. ※
Temperature Characteristics (Max Impedance Ratio)	Z(– 55°C)/ Z(+20°C) ≤ 1.25 (100kHz)
Endurance	The specifications listed at right shall be met when the capacitors are restored to 20°C after the rated voltage is applied for 4000 hours at 135°C. Capacitance change: Within ± 20% of initial capacitance value (※3) tan δ: 150% or less of the initial specified value ESR (※1): 200% or less of the initial specified value Leakage current (※2): Less than or equal to the initial specified value
Shelf Life	After storing the capacitors under no load at 135°C for 1000 hours and then performing voltage treatment based on JIS C 5101-4 clause 4.1 at 20°C, they shall meet the specified values for the endurance characteristics listed above.
ESR after Endurance (※1)	Less than or equal to the specified value at 100kHz, -40°C
Damp Heat (Steady State)	The specifications listed at right shall be met when the capacitors are restored to 20°C after the rated voltage is applied for 2000 hours at 85°C, 85% RH. Capacitance change: Within ± 20% of initial capacitance value (※3) tan δ: 150% or less of the initial specified value ESR (※1): 200% or less of the initial specified value Leakage current (※2): Less than or equal to the initial specified value
Resistance to Soldering Heat	After soldering the capacitor under the soldering conditions prescribed here, the capacitor shall meet the specifications listed at right. Pre-heating shall be done at 150 to 200°C and for 60 to 180 sec. The duration for over +230°C temperature at capacitor surface shall not exceed 60 seconds. In case peak temperature is 260°C or less, reflow soldering shall be two times maximum. Measurement for solder temperature profile shall be made at the capacitor top. Capacitance change: Within ± 10% of the initial capacitance value (※3) tan δ: 130% or less than the initial specified value ESR (※1): 130% or less than the initial specified value Leakage current (※2): Less than or equal to the initial specified value
Marking	Navy blue print on the case top

Table 4-9

- ## Dimensions:

Rated Voltage (V) (code)	Surge Voltage (V)	Rated Capacitance (μF)	Case Size ・D×L (mm)	tan δ	Leakage Current (μA) (at 20℃ after 2 minutes)	Initial ESR (mΩ) (20℃/100kHz)	Low temp. ESR after Endurance (mΩ) (−40℃/100kHz)	Rated Ripple (mArms) 35° /100kHz)	Part Number
16 (1C)	20	120	6.3 × 6	0.08	57	36	72	900	PCH1C121MCL1GS
		220	■ 6.3×8	0.08	105	23	46	1500	PCH1C221MCL4GS
		220	8 × 7	0.08	105	30	60	1100	PCH1C221MCL1GS
		470	▲ 8 × 10	0.08	225	17	34	2400	PCH1C471MCL6GS
		470	10 × 8	0.08	225	22	44	1900	PCH1C471MCL1GS
		560	8 × 12	0.08	268	16	32	2700	PCH1C561MCL1GS
		680	10 × 10	0.08	326	19	38	2300	PCH1C681MCL1GS
		1000	10 × 12.7	0.08	480	13	26	2500	PCH1C102MCL1GS
20 (1D)	25	100	6.3 × 6	0.08	60	41	82	900	PCH1D101MCL1GS
		150	■ 6.3×8	0.08	90	25	50	1200	PCH1D151MCL4GS
		150	8 × 7	0.08	90	39	78	800	PCH1D151MCL1GS
		330	▲ 8 × 10	0.08	198	19	38	2300	PCH1D331MCL6GS
		330	10 × 8	0.08	198	23	46	1800	PCH1D331MCL1GS
		470	8 × 12	0.08	282	18	36	2500	PCH1D471MCL1GS
		560	10 × 10	0.08	336	20	40	2200	PCH1D561MCL1GS
		680	10 × 12.7	0.08	408	14	28	3000	PCH1D681MCL1GS
25 (1E)	31	56	6.3 × 6	0.08	42	43	86	900	PCH1E560MCL1GS
		100	■ 6.3×8	0.08	75	27	54	1100	PCH1E101MCL4GS
		100	8 × 7	0.08	75	41	82	800	PCH1E101MCL1GS
		220	▲ 8 × 10	0.08	165	20	40	2300	PCH1E221MCL6GS
		220	10 × 8	0.08	165	24	48	1800	PCH1E221MCL1GS
		270	8 × 12	0.08	202	19	38	2300	PCH1E271MCL1GS
		330	10 × 10	0.08	247	20	40	2200	PCH1E331MCL1GS
		470	10 × 12.7	0.08	352	15	30	2900	PCH1E471MCL1GS
35 (1V)	43	47	6.3 × 6	0.08	49	48	96	800	PCH1V470MCL1GS
		68	■ 6.3×8	0.08	71	31	62	1100	PCH1V680MCL4GS
		68	8 × 7	0.08	71	44	88	800	PCH1V680MCL1GS
		150	▲ 8 × 10	0.08	157	22	44	2200	PCH1V151MCL6GS
		150	10 × 8	0.08	157	25	50	1800	PCH1V151MCL1GS
		220	8 × 12	0.08	231	21	42	2300	PCH1V221MCL1GS
		270	10 × 10	0.08	283	20	40	2200	PCH1V271MCL1GS
		330	10 × 12.7	0.08	346	16	32	2800	PCH1V331MCL1GS
		22	6.3 × 6	0.08	33	50	100	700	PCH1H220MCL1GS
		39	■ 6.3×8	0.08	58	36	72	900	PCH1H390MCL4GS
		39	8 × 7	0.08	58	45	90	900	PCH1H390MCL1GS

50 (1H)	63	82	▲ 8 × 10	0.08	123	26	52	2100	PCH1H820MCL6GS
		82	10 × 8	0.08	123	34	68	1600	PCH1H820MCL1GS
		120	△ 8 × 12	0.08	180	25	50	2100	PCH1H121MCL2GS
		120	10 × 10	0.08	180	25	50	2100	PCH1H121MCL1GS
		180	10 × 12.7	0.08	270	19	38	2500	PCH1H181MCL1GS
63 (1J)	79	12	6.3 × 6	0.08	22	51	102	700	PCH1J120MCL1GS
		22	■ 6.3×8	0.08	41	45	90	800	PCH1J220MCL4GS
		22	8 × 7	0.08	41	48	96	800	PCH1J220MCL1GS
		39	8 × 10	0.08	73	28	56	1900	PCH1J390MCL1GS
		47	10 × 8	0.08	88	35	70	1500	PCH1J470MCL1GS
		56	8 × 12	0.08	105	27	54	2100	PCH1J560MCL1GS
		68	10 × 10	0.08	128	28	56	2000	PCH1J680MCL1GS
		100	10 × 12.7	0.08	189	24	48	2100	PCH1J101MCL1GS
80 (1K)	100	12	6.3 × 8	0.08	28	50	100	800	PCH1K120MCL1GS
		27	8 × 10	0.08	64	38	76	1000	PCH1K270MCL1GS
		39	8 × 12	0.08	93	35	70	1100	PCH1K390MCL1GS
		47	10 × 10	0.08	112	33	66	1200	PCH1K470MCL1GS
		68	10 × 12.7	0.08	163	28	56	1500	PCH1K680MCL1GS

Table 4-10

ZMPT101B

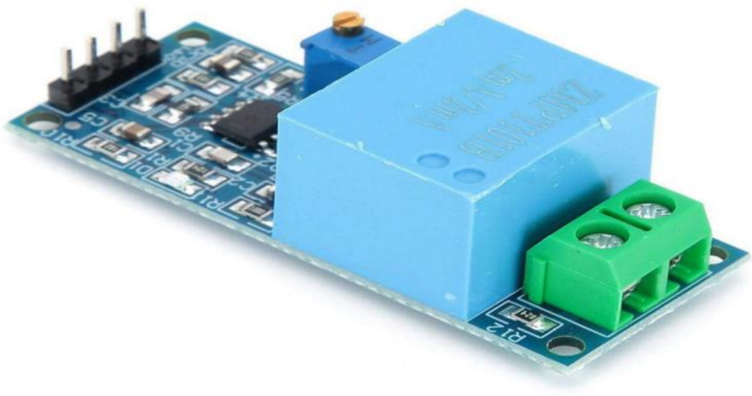
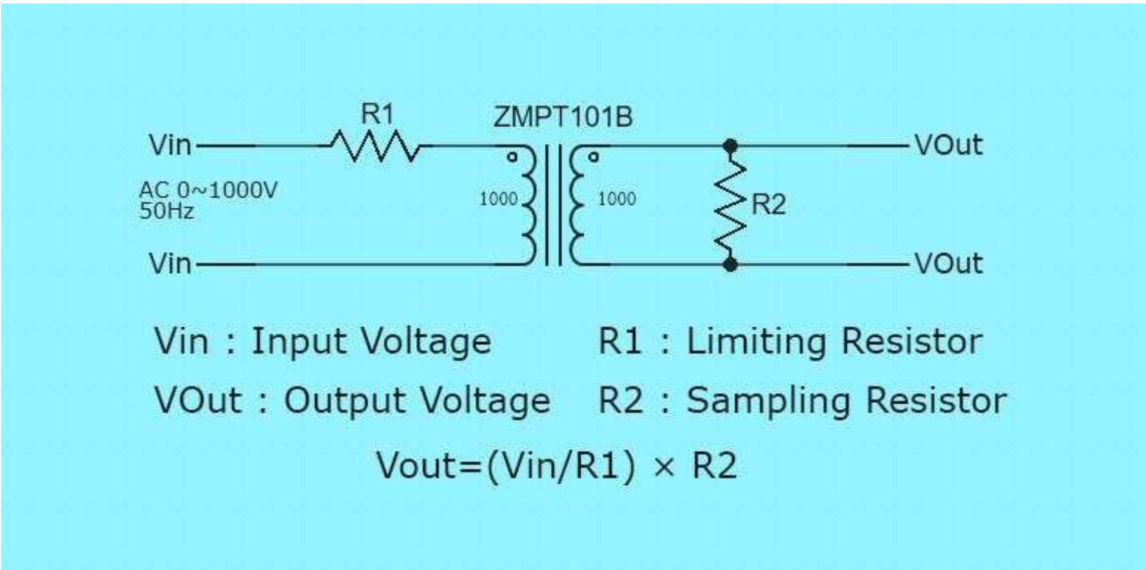


Figure4.12

MICRO PRECISION VOLTAGE TRANSFORMERS
ZMPT101B schematic/ Wiring Diagram



Description

ZMPT101B AC Voltage Sensor is the best for the purpose of the DIY project, where we need to measure the accurate AC voltage with voltage transformer. ZMPT101B is an ideal choice to measure the AC voltage using Arduino/ESP8266/Raspberry Pi like an opensource platform. In many electrical projects, engineer directly deals with measurements with few basic requirements like

- High galvanic isolation
- Wide Range
- High accuracy
- Good Consistency

ZMPT101B is a high precision voltage Transformer. This module makes it easy to monitor AC mains voltage upto 1000 volts. A tiny little thing the size of a bouillon cube. Holds up to 4kV per breakdown voltage, the ratio of turns is 1: 1, but this is a current transformer of 2mA: 2mA. That is, we feed it a current and remove the current. The input current is simply set by the resistor in series R1, and a sampling resistor R2 is used in parallel to obtain the output voltage.

R1 is chosen so that the current through the winding does not exceed 2mA, it holds a maximum of 10mA, but after 2mA linearity is lost and the output will be clear that.

Step 1: Determination of maximum output rms voltage

VOutmax is decided by the ADC peak voltage in the sampling loop of Microcontroller.

For Bipolar ADC

$\text{VOutmax} = \frac{Peak\ Voltage}{\sqrt{2}}$ For example

As for ± 5V ADC, the maximum rms voltage of the transformer:

$$\text{VOutmax} = \frac{Peak\ Voltage}{\sqrt{2}} = \frac{5V}{\sqrt{2}} = 3.53V$$

For Unipolar ADC

$$\text{VOutmax} = \frac{Peak\ Voltage}{2\sqrt{2}}$$

For example

As for 0-3.3V ADC, the maximum rms voltage of the transformer:

$$\text{VOutmax} = \frac{Peak\ Voltage}{2\sqrt{2}} = \frac{3.3V}{2\sqrt{2}} = 1.16V$$

Step 2: Determination of input current-limiting resistor R1

Current-limiting resistor

$$R1 = \frac{Vin}{I}$$

Where

Vin：Rated input voltage

I ：Rated operating current （when Coil resistance is compared with current-limiting resistor R1, it can be ignored.）

ZMPT101B usually working at rated current**: 1~2mA.**

When Rated input voltage ≤ 100V， Usually choosing the operating current I=2mA; When Rated input voltage ≥ 220V，To reducing the resistor power， usually choosing the operating current **1 mA ≤ I ≤ 2 mA**.

for example: V=100V， I=2 mA,

$$R1 = \frac{Vin}{I} = \frac{100}{0.002} = 50k\Omega$$

for example: V=220V， I=1.1 mA,

$$R1 = \frac{Vin}{I} = \frac{220}{0.0011} = 200k\Omega$$

To improve reliability, the current-limiting resistor selected usually is greater than its 4times the rated power, and generally use a high temperature coefficient metal film resistor.

Step 3: Determination of the sampling resistor R2

$$R2 = \frac{VOutmax}{I} = \frac{VOutmax}{Vin} \times R1\ \Omega$$

for example: Voutmax =3.53V， Vin =100V

$$R2 = \frac{VOutmax}{I} = \frac{VOutmax}{Vin} \times R1 = \frac{3.53}{100} \times 50\ k\Omega = 1.765k\Omega$$

- Above formula is also suitable for the two ways of active and passive output.
- When selecting the sampling resistor, Resistor should not exceed

$$R2 = \frac{VOutmax}{I} = \frac{VOutmax}{Vin} \times R1\ \Omega$$

Relay Module:

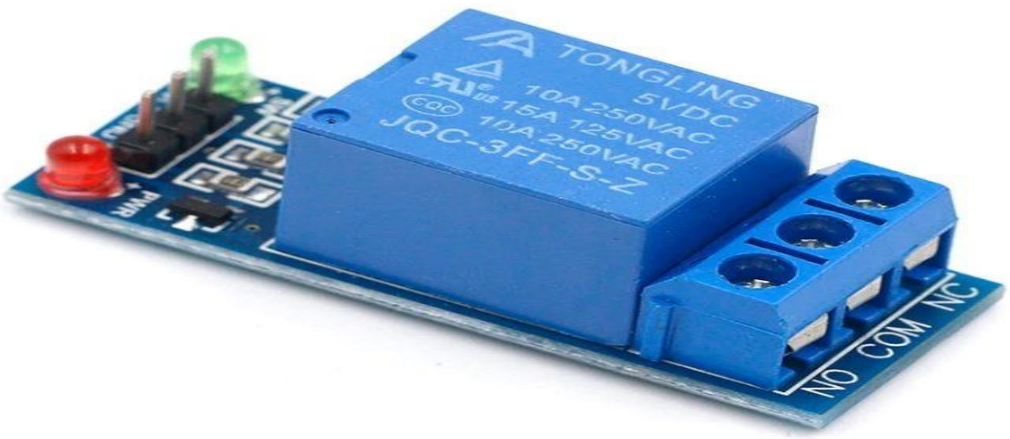


Figure 4.13

This is a LOW Level 5V 1-channel relay interface board, needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller. This module is optically isolated from high voltage side for safety requirement and also prevent ground loop when interface to microcontroller.

Brief Data:

- Operating Voltage: 5Vdc.
- Relay Maximum output: DC 30V/10A, AC 250V/10A.
- 1 Channel Relay Module with Opto-coupler. LOW Level Trigger expansion board, which is compatible with Arduino control board.
- Standard interface that can be controlled directly by microcontroller (8051, AVR, *PIC, DSP, ARM, ARM, MSP430, TTL logic).
- Relay of high quality low noise relays SPDT. A common terminal, a normally open, one normally closed terminal.
- Opto-Coupler isolation, for high voltage safety and prevent ground loop with microcontroller.

Schematic:

VCC and RY-VCC are also the power supply of the relay module. When you need to drive a large power load, you can take the jumper cap off and connect an extra power to RY-VCC to supply the relay; connect VCC to 5V of the MCU board to supply input signals.

NOTES: If you want complete optical isolation, connect "Vcc" to Arduino +5 volts but do NOT connect Arduino Ground. Remove the Vcc to JD-Vcc jumper. Connect a separate +5 supply to "JD-Vcc" and board Gnd. This will supply power to the transistor drivers and relay coils.

If relay isolation is enough for your application, connect Arduino +5 and Gnd, and leave Vcc to JD-Vcc jumper in place.

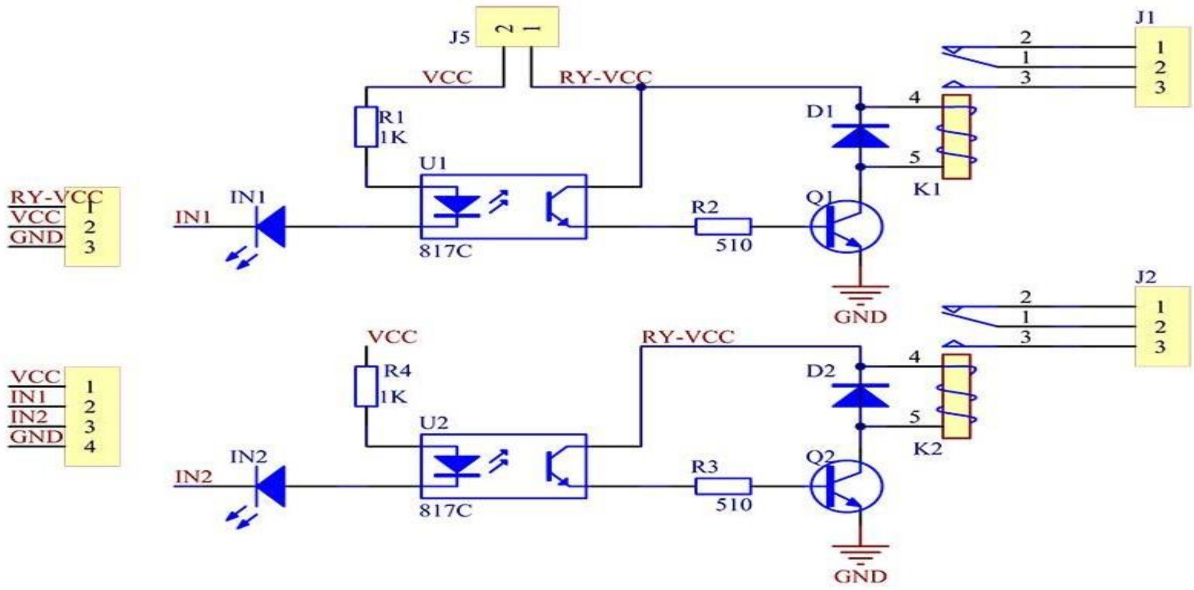


Figure4.14

It is sometimes possible to use this relay boards with 3.3V signals, if the JD-VCC (Relay Power) is provided from a +5V supply and the VCC to JD-VCC jumper is removed. That 5V relay supply could be totally isolated from the 3.3V device, or have a common ground if opto-isolation is not needed. If used with isolated 3.3V signals, VCC (To the input of the opto-isolator, next to the IN pins) should be connected to the 3.3V device's +3.3V supply.

NOTE: Some Raspberry-Pi users have found that some relays are reliable and others do not actuate sometimes. It may be necessary to change the value of R1 from 1000 ohms to something like 220 ohms, or supply +5V to the VCC connection.

Operating Principle:

See the picture below: A is an electromagnet, B armature, C spring, D moving contact, and E fixed contacts. There are two fixed contacts, a normally closed one and a normally open one. When the coil is not energized, the normally open contact is the one that is off, while the normally closed one is the other that is on.

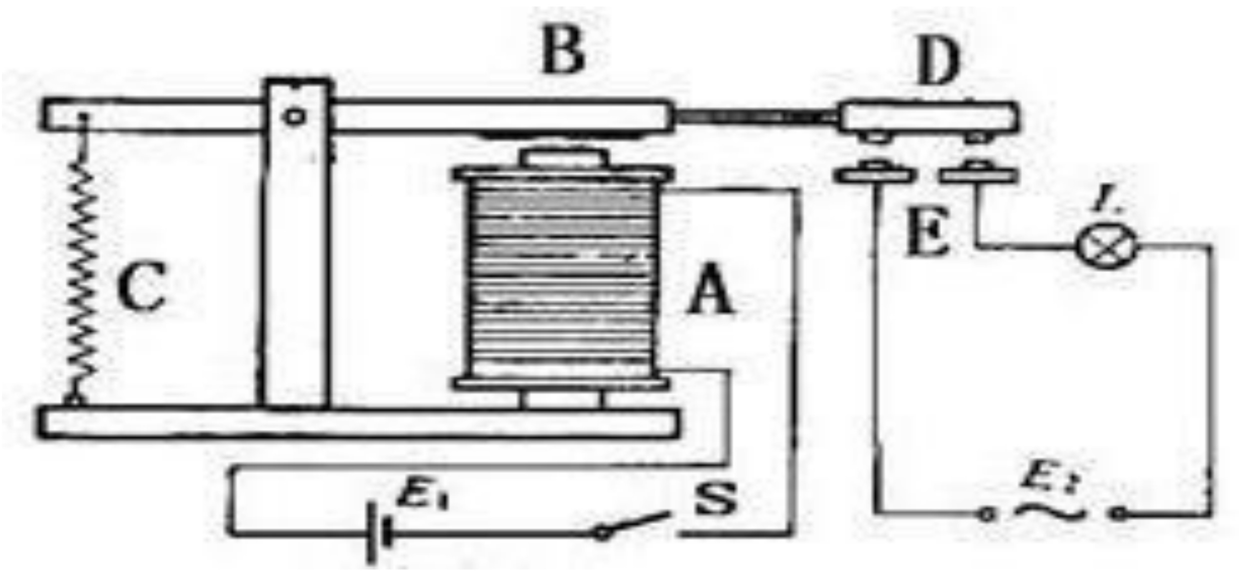


Figure4.15

Supply voltage to the coil and some currents will pass through the coil thus generating the electromagnetic effect. So the armature overcomes the tension of the spring and is attracted to the core, thus closing the moving contact of the armature and the normally open (NO) contact or you may say releasing the former and the normally closed (NC) contact. After the coil is de-energized, the electromagnetic force disappears and the armature moves back to the original position, releasing the moving contact and normally closed contact. The closing and releasing of the contacts results in power on and off of the circuit.

Input:

VCC: Connected to positive supply voltage (supply power according to relay voltage).

GND: Connected to supply ground.

IN1: Signal triggering terminal 1 of relay module.

Output:

Each module of the relay has one NC (normally close), one NO (normally open) and one COM (Common) terminal. So there are 2 NC, 2 NO and 2 COM of the channel relay in total. NC stands for the normal close port contact and the state without power. NO stands for the normal open port contact and the state with power. COM means the common port. You can choose NC port or NO port according to whether power or not.

Testing Setup:

When a low level is supplied to signal terminal of the 2-channel relay, the LED at the output terminal will light up. Otherwise, it will turn off. If a periodic high and low level is supplied to the signal terminal, you can see the LED will cycle between on and off.

solar module

Figure 4.16

20w solar panel have some different from the 10w poly solar panels, 20w panel solar panels can be used in 20w solar system, which can provide more power than 10w small solar system, and it can lightning more bulbs and bigger batteries to store the energy generated by the solar panels.

Parameter Of 20W Poly Solar Panel With 36 Pieces Solar Cells

Electrical Characteristics Of 20W Poly Solar Panel With 36 Pieces Solar Cells

Module Type

SLB36P6–20

Maximum Power (W)

20

Tolerance Wattage (W)

0~+5

Optimum Power Voltage (VMP)
18.36
Optimum Operating Current (IMP)
1.09
Open Circuit Voltage (VOC)
21.96
Short Circuit Current (ISC)
1.18
Module Efficiency (%)
12.99
As a professional solar energy equipment manufacturer, we provide solar plate 200 watt, 200 watt solar power kit, 20w solar panel kit, solar system for home and etc. Want to know 20w solar panel price or more, contact us.

ADS1115 Analog-to-Digital Converter

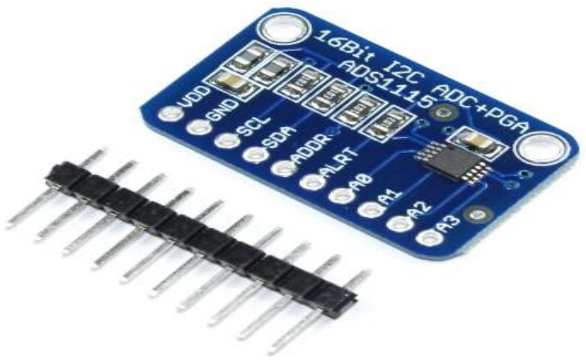


Figure 4.17

FEATURES

- **ULTRA-SMALL QFN PACKAGE: 2mm × 1,5mm × 0,4mm**
- **WIDE SUPPLY RANGE: 2.0V to 5.5V**
- **LOW CURRENT CONSUMPTION: Continuous Mode: Only 150µA Single-Shot Mode: Auto Shut-Down**
- **PROGRAMMABLE DATA RATE: 8SPS to 860SPS**
- **INTERNAL LOW-DRIFT VOLTAGE REFERENCE**
- **INTERNAL OSCILLATOR**
- **INTERNAL PGA**
- **I²C™ INTERFACE: Pin-Selectable Addresses**
- **FOUR SINGLE-ENDED OR TWO DIFFERENTIAL INPUTS (ADS1115)**
- **PROGRAMMABLE COMPARATOR (ADS1114 and ADS1115)**

APPLICATIONS

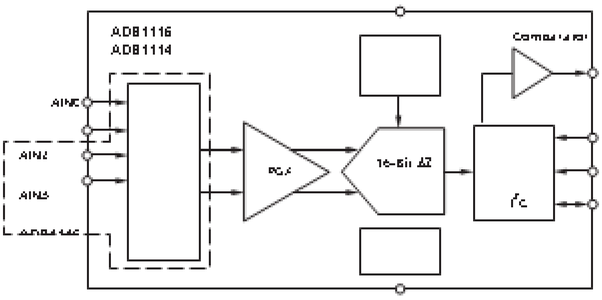
- **PORTABLE INSTRUMENTATION**

DESCRIPTION

The ADS1113, ADS1114, and ADS1115 are precision analog-to-digital converters (ADCs) with 16 bits of resolution offered in an ultra-small, leadless QFN-10 package or an MSOP-10 package. The ADS1113/4/5 are designed with precision, power, and ease of implementation in mind. The ADS1113/4/5 feature an onboard reference and oscillator. Data are transferred via an I²C-compatible serial interface; four I²C slave addresses can be selected. The ADS1113/4/5 operate from a single power supply ranging from 2.0V to 5.5V.

The ADS1113/4/5 can perform conversions at rates up to 860 samples per second (SPS). An onboard PGA is available on the ADS1114 and ADS1115 that offers input ranges from the supply to as low as ±256mV, allowing both large and small signals to be measured with high resolution. The ADS1115 also features an input multiplexer (MUX) that provides two differential or four single-ended inputs.

The ADS1113/4/5 operate either in continuous conversion mode or a single-shot mode that automatically powers down after a conversion and greatly reduces current consumption during idle



ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of thisdocument, or see the TI web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

	ADS1113, ADS1114, ADS1115	UNIT
VDD to GND	–0.3 to +5.5	V
Analog input current	100, momentary	mA
Analog input current	10, continuous	mA
Analog input voltage to GND	–0.3 to VDD + 0.3	V
SDA, SCL, ADDR, ALERT/RDY voltage to GND	–0.5 to +5.5	V
Maximum junction temperature	+150	°C
Storage temperature range	–60 to +150	°C

Table 4-11

PRODUCT FAMILY

DEVICE	PACKAGE DESIGNATOR MSOP/QFN	RESOLUTION (Bits)	MAXIMUM SAMPLE RATE (SPS)	COMPARATOR	PGA	INPUT CHANNELS (Differential/ Single-Ended)
ADS1113	BROI/N6J	16	860	No	No	1/1
ADS1114	BRNI/N5J	16	860	Yes	Yes	1/1
ADS1115	BOGI/N4J	16	860	Yes	Yes	2/4
ADS1013	BRMI/N9J	12	3300	No	No	1/1
ADS1014	BRQI/N8J	12	3300	Yes	Yes	1/1
ADS1015	BRPI/N7J	12	3300	Yes	Yes	2/4

Table 4-12

TIMING REQUIREMENTS

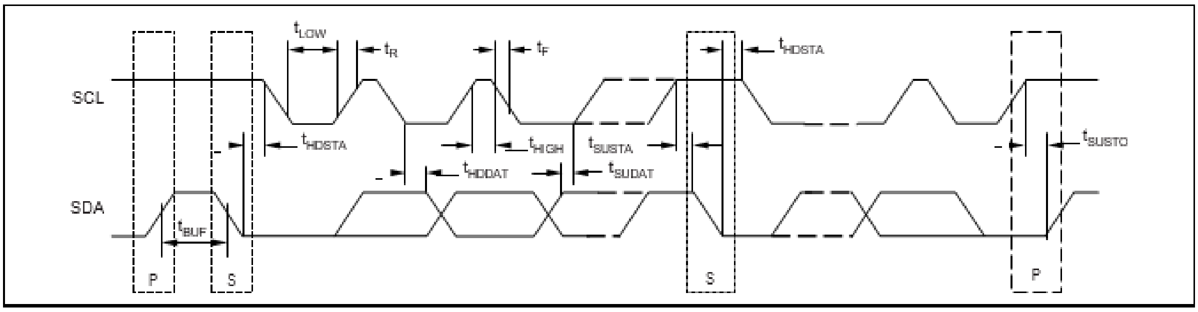


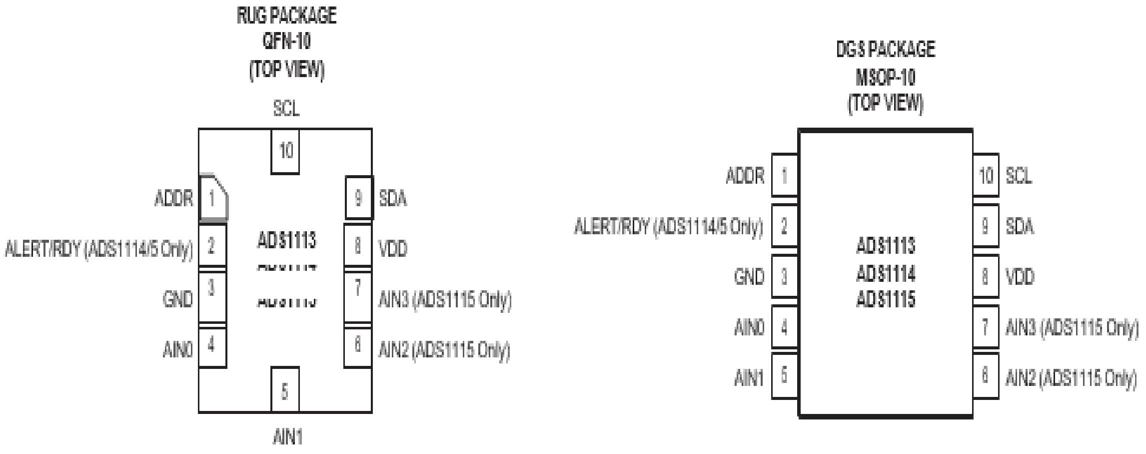
Figure 4.18

ELECTRICAL CHARACTERISTICS (continued)

PARAMETER	TEST CONDITIONS	ADS1113, ADS1114, ADS1115			UNIT
		MIN	TYP	MAX	
POWER-SUPPLY REQUIREMENTS					
Power-supply voltage		2		5.5	V
Supply current	Power-down current at 25°C		0.5	2	μA
	Power-down current up to 125°C			5	μA
	Operating current at 25°C		150	200	μA
	Operating current up to 125°C			300	μA
Power dissipation	VDD = 5.0V		0.9		mW
	VDD = 3.3V		0.5		mW
	VDD = 2.0V		0.3		mW
TEMPERATURE					
Storage temperature		–60		+150	°C
Specified temperature		–40		+125	°C

Table 4-13

PIN CONFIGURATIONS



PIN DESCRIPTIONS

PIN #	DEVICE			ANALOG/ DIGITAL INPUT/ OUTPUT	DESCRIPTION
	ADS1113	ADS1114	ADS1115		
1	ADDR	ADDR	ADDR	Digital Input	I^2C slave address select
2	NC[1]	ALERT/RDY	ALERT/RDY	Digital Output	Digital comparator output or conversion ready (NC for ADS1113)
3	GND	GND	GND	Analog	Ground
4	AIN0	AIN0	AIN0	Analog Input	Differential channel 1: Positive input or single-ended channel 1 input
5	AIN1	AIN1	AIN1	Analog Input	Differential channel 1: Negative input or single-ended channel 2 input
6	NC	NC	AIN2	Analog Input	Differential channel 2: Positive input or single-ended channel 3 input (NC for ADS1113/4)
7	NC	NC	AIN3	Analog Input	Differential channel 2: Negative input or single-ended channel 4 input(NC for ADS1113/4)
8	VDD	VDD	VDD	Analog	Power supply: 2.0V to 5.5V
9	SDA	SDA	SDA	Digital I/O	Serial data: Transmits and receives data
10	SCL	SCL	SCL	Digital Input	Serial clock input: Clocks data on SDA

Table 4-14

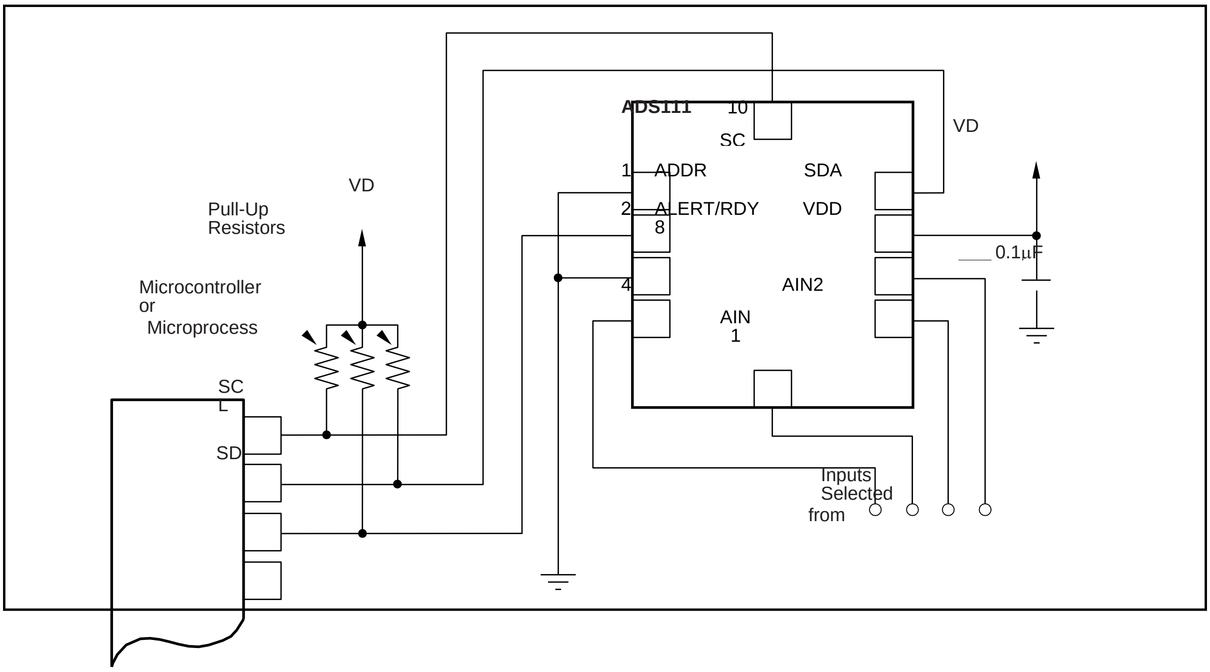


Figure 17 . Typical Connections of the ADS1115

Voltage Sensor DC

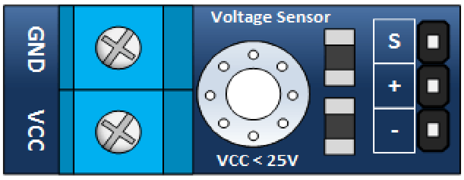
Arduino 25V Voltage Sensor Module

The Basics

Figure 4.15

The Arduino analog input is limited to a 5 VDC input. If you wish to measure higher voltages, you will need to resort to another means. One way is to use a voltage divider. The one discussed here is found all over Amazon and eBay.
It is fundamentally a 5:1 voltage divider using a 30K and a 7.5K Ohm resistor.
Keep in mind, you are restricted to voltages that are less than 25 volts. More than that and you will exceed the voltage limit of your Arduino input.

Basic Connection



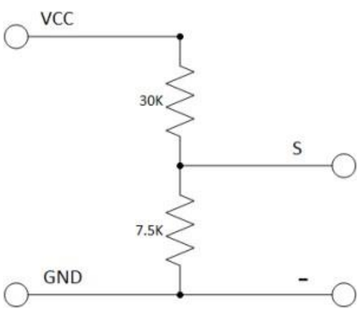
Inputs

- **GND –** This is where you connect the low side of the voltage you are measuring. Caution! : This is the same electrical point as your Arduino ground.
- **VCC:** The is where you connect the high side of the voltage you are measuring

Outputs

- **S:** This connects to your Arduino analog input.
- **– (or minus):** This connects to your Arduino ground.
- **+:** This is not connected. It does absolutely nothing… zilch… nada… jack diddly doo doo.

Schematic



The schematic for this is pretty straight forward. As previously mentioned, its just a couple of resistors. In fact, you could build your own in a pinch.

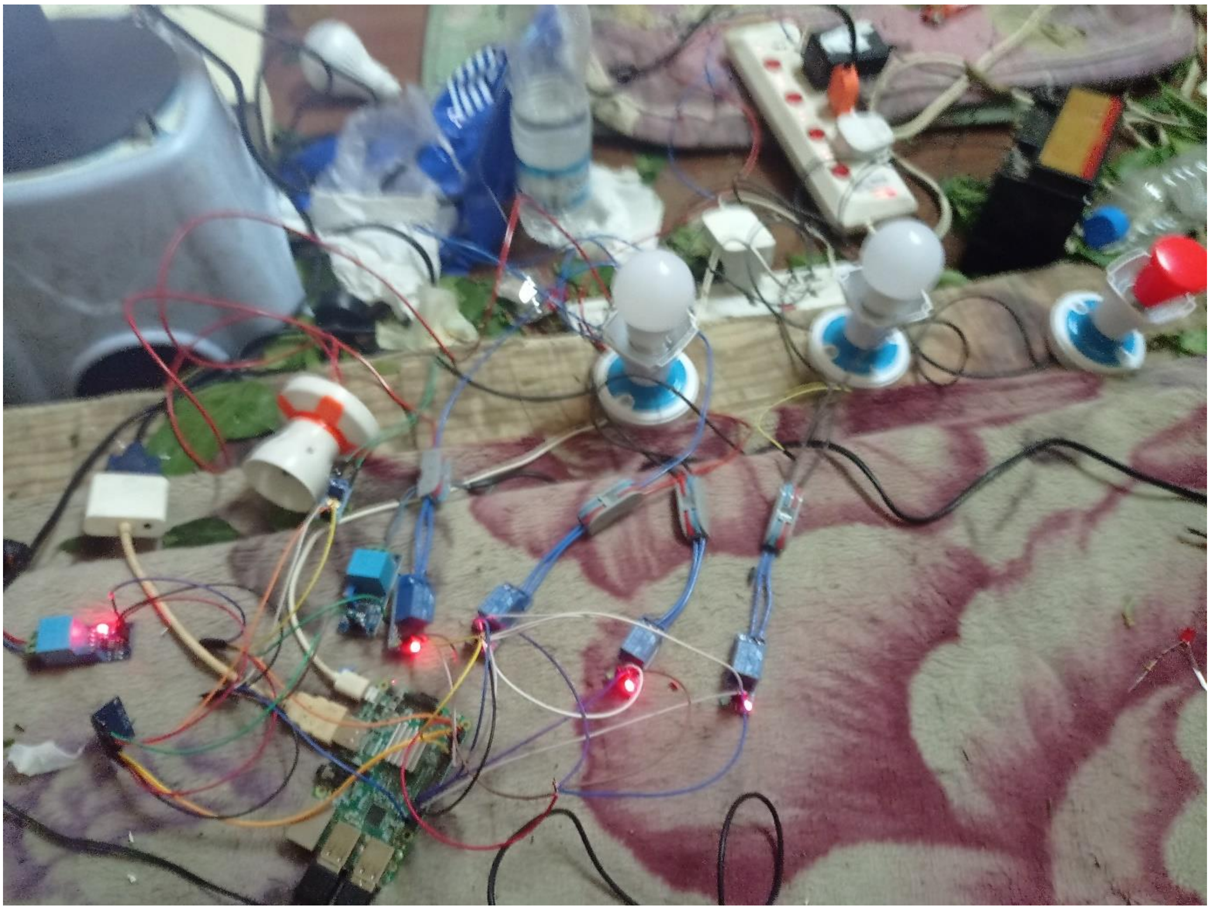
Chapter 5

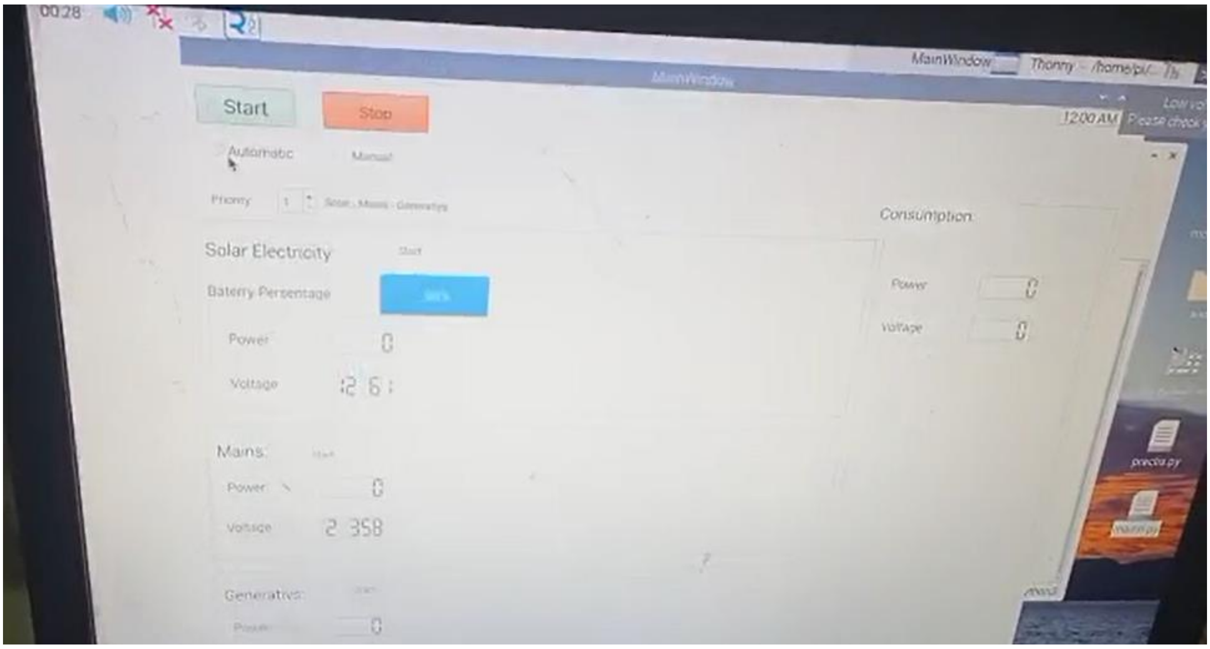
Implementation and Test

Chapter 5: Implementation and Test

Introduction:

Initially, we worked on the model (the mini project), and after that we installed the servo, the solar panels, and the motion sensor. After that, we made the electrical drum and installed the multiple sources of solar energy, public electricity, and the generator, and operated the generator automatically. Below are illustrative pictures of how Installation of the model.




MainWindow
Start
Stop
Automatic
Manual
Consumption
Solar Electricity
Batery Persentage
Power
Voltage
Mains
Generative

Chapter 6

Results and Discussions

Alhamud Alalah, we obtained excellent results. There were some difficulties in the work from a programming perspective, but they were overcome, and difficulties in installing the model and operating the electrical circuit, but after the conversion and repetition in the conversion, all the difficulties that we faced were overcome, and the results were excellent.

1- **The servos and sun tracking sensor were operated well and were moved up and down and to the right and left perfectly.**

2- **The Arduino control was activated to move the boards and servos without any difficulties.**

3- **Multiple sources were operated, and the sources were expressed using electric bulbs, and they were operated perfectly.**

4- **The HMI was operated perfectly after programming it and determining the screen measurements.**

5- **Multiple sources and the control point were activated via the Raspberry Pi.**

The discussion was excellent, thanks to our great doctors, and we focused on one mistake in our project. If we do our project in hospitals, the hospital equipment is very sensitive. Even if the source transmission is 0.0001, it senses and turns off. Therefore, we will add a device that changes the current without disconnecting the devices. Sensitive devices such as medical devices.
We were working on the code to enter the system through the fingerprint, the users only, and the database, but the time was limited to present the project to those who were able to complete the project completely, but we will complete it.

Chapter 7

Conclusions and Recommendations

Chapter 7: Conclusions and Recommendations

Conclusions:

1. Analyzing data collected from a SCADA system can help improve energy efficiency.
2. Monitoring the condition of devices and equipment associated with the system can lead to the implementation of sustainable maintenance and avoid unplanned downtime.

3. Using SCADA data can improve process performance and contribute to system sustainability.

4. Automated power distribution control can be achieved through SCADA system, resulting in more efficient distribution and avoiding outage hypothesis.

5. Using advanced analytics and informed decision making can bring significant improvements in energy efficiency and future planning.

Recommendations:

1. Use SCADA data to identify opportunities to optimize energy consumption and take actions to improve efficiency.

2. Plan sustainable maintenance and monitoring of devices and equipment associated with the system to avoid unplanned downtime and ensure system sustainability.

3. Use SCADA data and advanced analytics to improve process performance and avoid problems and malfunctions.

4. Implement automatic power distribution control using SCADA system to achieve more efficient distribution and avoid the premise of outage in high demand situations.

5. Use advanced analytics and data from SCADA to make informed strategic decisions to improve efficiency and plan for the future.

References

- **Solid Works:** We used this program to design the internal and external structure.
(https://www.solidworks.com/support/free-downloads)
- **Proteus:** We used this program to test the electric circuit and run it theoretically.
(https://www.solidworks.com/support/free-downloads)
- **PyCharm Community Editio:** Using this program, the Python language was programmed.
(https://www.python.org/downloads)
- **Arduino:** We used this program to program the Arduino controllers.
(https://www.arduino.cc/en/software/)
- **Lanax:** We used this system for the Raspberry Pi controller**.**
(https://www.raspberrypi.com)
- **HMI:** These interfaces were designed using QT Designer**.**
(https://build-system.fman.io/qt-designer-download)