MICROCONTROLLER FOR SUN PHOTOMETER

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Abstract: Present article deals with selection and study of microcontroller required for the construction of modern sun photometer. Construction of photometer essentially requires parts like ADC, floating point processor, electrically erasable memory and input /output (IO) ports. Development of microelectronics is now a constant process and the new devices like Bluetooth and Wi-Fi would make sun photometer portable so that it can be placed at remote locations. In recent years, there is tremendous development in the microcontroller capability particularly in the field of data conversion, digital communication and arithmetic processing. Use of such microcontroller improves the performance of photometer particularly the parameters like sensitivity, accuracy and precision are improved. This article is helpful to the instrumentation engineers and researchers working in the field of astronomy and astrophysics.

Index Term: **Microcontroller, Bluetooth, Wi-Fi, photometer.**

I. INTRODUCTION

Photometer is one of the widely used instruments in the field of astrophysics. It is used for measuring the light intensity and the spectral response of sunlight (David et al., 2001). Astrophysicist uses it for the study of medium between earth and sun, and also for the study of thermal and optical properties of sun. Apart from this it is also used for the measurement of optical density in the area of photo development laboratories for colour management, measurement of optical density in colorimetry for the detection of analyte, and in space physics it is used for the detection of light absorbed by aerosols. In early years of 20th century photometer was the only instrument available for direct measurement of light intensity. It was constructed from components like photoconductive cells and anolog electronic devices like vacuum tubes. The sun photometer evolved with the development in the field of microelectronics, particularly in the field of integration of discrete components on silicon chip.

In the early period of 20th century, photometers were constructed using selenium photocell, vacuum tube based amplifier and permanent magnet meter. Such meters were bulky, expensive and rarely used in observatories. In 1970s, they were constructed using photoconductive cells, transistorised amplifier and LED based seven segment display. By the end of 20th century they were constructed using photocell, microprocessor based display. During the first 10 years of 21st century they were constructed from photocell microcontroller based measurement system and LCD. Nowadays, there is tremendous development in the field of microcontroller technology which as improved the integration level as well as the computational power. Such microcontrollers are more suitable for the design of sun photometer because they improve the performance parameters of system.

Sensitivity, accuracy and precision are the three main performance parameters of any sun photometers. The modern microcontrollers help to improve these parameters, for instance, sensitivity is improved due to high resolution ADC, and similarly accuracy is improved by use of floating point computational facility of microcontroller. The scratch pad memory helps to improve the precision. They also make the equipment long lasting, sophisticated and easy to use. Modern microcontrollers consume less power and they operate at low voltage. The instrument based on them can be battery operated compact and portable.

In the present work we have studied modern microcontrollers and also checked their usability in making of sun photometer. The work is helpful to the electronic designers working in the field of astrophysics.

II. METHODS

Microcontrollers are basically designed by the theory proposed by Von Neumann or Harvard. Von Neumann had proposed the first hypothetical computational system but Harvard architecture is preferred because of its possible practical implementation. Figure 1 shows the models proposed by Von Neumann and Harvard. The main use of microcontroller is to execute the programs written in assembly language. Assembly language has set of instructions for accessing the microcontroller memory and ports. Instruction set could be CISC or RISC type, and on the basis of that the architecture of microcontroller is designed as shown in Fig. 2. CISC has many instructions but RISC has less instructions (Leventhal , 1978).

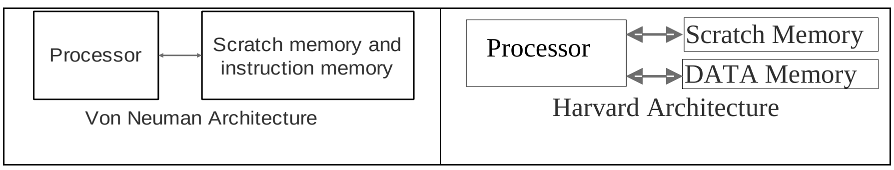

Figure 1: Basic models of processor

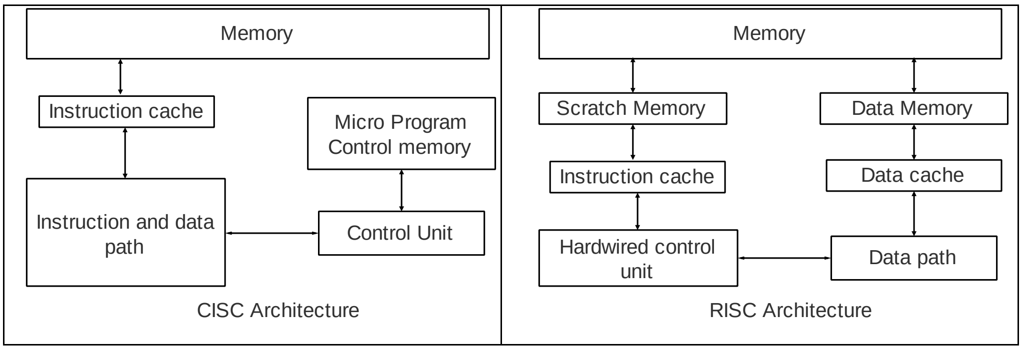

Figure 2: CPU types on the basis of instructions

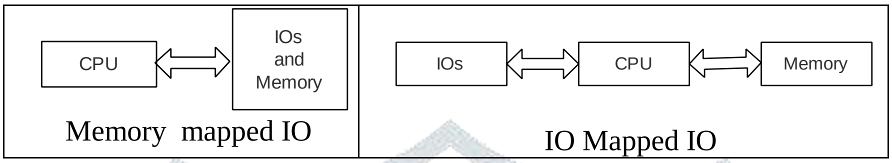

Figure 3: Types of IO

The main parts of microcontroller are ALU, registers, memory and port. Some microcontrollers have separate address space for the memory and ports they are generally termed as IO mapped IO type controllers. In some microcontrollers registers and ports are part of memory space and they are termed as memory mapped IO type controllers as shown in fig. 3(Martin, 1978).

There are many variations in the design of microcontroller particularly in the area of integration of peripheral devices. Each manufacturer makes some change in the design, for example, a leading industry microchip has manufactured a series of microcontrollers popularly known as PIC (Peripheral Interface Controller) microcontrollers. PIC microcontroller integrates more peripherals. Another popular series of microcontroller manufactured by Atmel is AVR (Advanced Virtual RISC) microcontroller that has some advancement in its design due to which it is more used in robotics and Arduino boards. (Mazidi et al, 2009)Among all microcontrollers level ARM (Advanced RISC Machines) microcontrollers are more popular in industries due to its more computational power and high integration.

PIC, AVR and ARM are most popular industrial microcontrollers and they can also be used in the design of sun photometer. But they are not sufficient to make a complete portable wireless sun photometer. In recent days, there has been much good development in the hardware required for internet or wireless communication. Many new devices are coming in the market which has either Wi-Fi or Bluetooth wireless facility. A recent development by Espressif Systems, a Shanghai-based Chinese industry in the field of microcontroller has attractive features and captured majority of market in the Wi-Fi field. One of their product i.e. ESP32 is selected for the sun photometer work and now discussed in the present article.

III. Wireless Microcontroller For Photometer

Any microcontroller is suitable for sun photometer. Sun photometer requires data conversion, data manipulation, data recording, data read out devices and data communication. These devices with more or less capacity are available in any microcontroller.

Data conversion: It converts analog data into digital and vice versa. It is one of the complex unit of microcontroller because of its various requirements like sample and hold of signal, quantization, conversion time, etc. Many techniques are possible like dual slope ADC, successive approximation (SA) ADC and sigma delta (SD) ADC each have advantages as well as disadvantages, but successive approximation and SD are commonly used in microcontroller because of their computational implementation of repetitive work. SA is one of the fastest ADC but its resolution is limited to 10 or 12 bit. Dual slope is generally not integrated because of big value capacitor. SD is relatively new method; it gives resolution upto 24 bit. Table 1 shows the data conversion specification of popular microcontrollers.

Table 1: A data conversion of some microcontrollers

Sr No	Name of Microcontroller	Data conversion features			Data size
		Resolution	Method	Channels	
1	Atmel 89C51	-	-	-	8
2	AVR 328P	10	SAR	6	8
3	PIC 18F4520	10	SAR	13	16
4	ARM ADuC7061	24	Sigma Delta	10	32
5	AT91SAM3X8E	12	SAR	16	32
6	ESP 32	12	SAR	18	32

Data manipulation: It is generally a data modification with the use of arithmetic operators. Each microcontroller supports basic operators i.e. +, -, x, /, the first three operators give exact results but the fourth one i.e division gives round result for mixed data type. It should be minimised by the software techniques. Rounding error is less for wide data handling processors.

Data recording: It is necessary for offline computation like data analysis and visualization. If storage is non-volatile then data can lasts for longer period. Modern microcontrollers have an erasable memory implemented in EEPROM which is suitable for the purpose of data recording. Table 2 show data recording facility available in different microcontrollers.

Table 2: Memory and communication features of some microcontrollers

Sr No	Name of Microcontroller	Types of memories (kb)			Communication features
		Flash	Scratch pad	EEPROM	
1	Atmel 89C51	4kbytes	64kb	--	Parallel, serial
2	AVR 328P	32k	2k	1k	Parallel, serial
3	PIC 18F4520	32k	1536byte	256 byte	Parallel, serial
4	ARM ADUC7061	32k	4k	1k	Parallel, serial
5	AT91SAM3X8E	512k	96k	16k	Parallel, serial, ethernet
6	ESP32	448k	520k	8k	Parallel, serial, Wi-Fi, bluetooth

Data read out devices: No microcontroller directly supports a read out device, but the read out device can be interfaced to the microcontroller via its ports. A microcontroller should have sufficient GPIO pins for interfacing the read out device. Now days, a character LCD like 16x2 or 20x4 LCD are the preferred read out devices because of their easy interfacing, inexpensive and less power consumption.

Data communication: In present days, if any development is in progress in the microcontrollers then that is in the field of data communication. Communication could be wired or wireless. For wired communication there are many options like parallel, serial, USB, I2C, etc. Wireless communication is recently used in some processors and it could be either bluetooth or wireless. Table 2 shows communication features of microcontrollers.

IV. Microcontroller Based Sun Photometer

Sun photometer is a complete instrumentation system. It includes everything which a typical instrument has in its design. Figure 4 shows a general block diagram of sun photometer. Sensor is photoconductive light dependent resistor which transforms changes in light into electric signal, which is further amplified by a linear amplifier such as close loop op-amp. The linear signal from op-amp is digitised, manipulated, recorded and communicated to a host device by microcontroller unit. Microcontroller includes various units necessary for sun photometer. Figure 5 shows the generic block diagram of modern microcontroller suitable for the design of sun photometer.

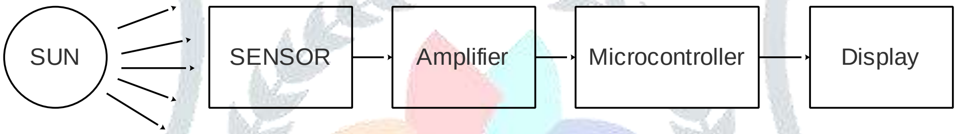

Figure 4: General block diagram of sun photometer

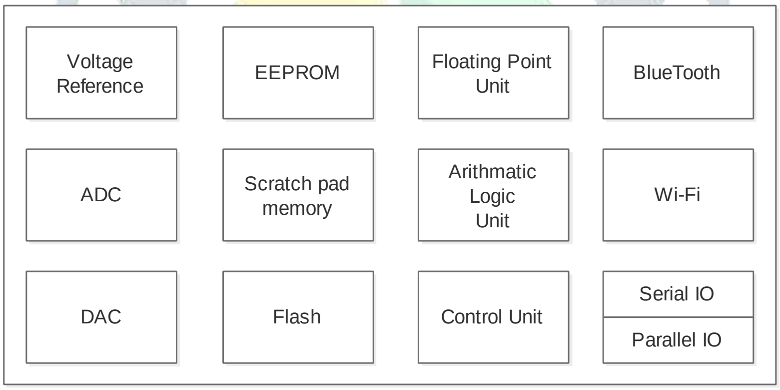

Figure 5: Generic block diagram of modern microcontroller.

V. Programming Of Microcontroller

Microcontrollers are used in some applications which require a software program or doing a task for application. In sun photometer the software program performs following functions: data conversion, manipulation, analysis, storage and communication. For each of these functions set of assembly language instructions or statements of high level language are required. For instance, we have used ESP32 in our sun photometer and programmed it using open source Arduino nightly software. The common instructions and their functions are given in table 3.

VI. Setting Of Software Environment

The IDE programs like Arduino nightly support many microcontrollers so that it can be used for programming different type of microcontrollers. There is need of setting parameters of IDE like name and number of processors, port number, type of burner programme, etc. Since Arduino lightly is open source software, some libraries also should be included in it those are linked by linker program of IDE.

Table 3: common instructions required for microcontroller programming

Statement	Use	Purpose in the sun photometer
pinMode(pin, mode)	To configure a specified pin to behave as an INPUT or an OUTPUT	pinMode (pin, output) sets 'pin' to output
digitalWrite (pin, value)	Outputs either logic level HIGH or LOW	digitalWrite (pin, high) sets 'pin' at high
digitalRead (pin)	Reads the value from a specified digital pin	Value = digitalRead (pin) state of pin is assigned to value
analogRead (pin)	Reads the value from a specified analog pin	Value = analogRead (pin) Sets 'value' equal to 'pin'
analogWrite (pin, value)	Writes analog value using PWM to an output pin	analogWrite (pin, value) writes 'value' to analog 'pin'
Delay (ms)	Pauses program for the amount of times	delay (1000) wait for one second
Min(x,y)	returns the smaller number	Value = min (value, 10)
Serial.begin (rate)	Opens serial port and sets the baud rate	Serial.begin (9600) Rate of transmission is 9600
Serial.println (data)	Prints data to the serial port	Serial.println (value) Sends value of 'value'

VII. Conclusions

In the present work some microcontrollers are studied and their suitability in the design of sun photometer is checked. Among all of them we prefer ESP32 because of its additional feature of bluetooth and Wi-Fi. Its other features like touch sensor, multi channel ADC, many reconfigurable PWM pins makes it as ideal choice for sun photometer. Another purpose of selecting it is due to the availability of open source software like IDE and libraries. Its availability in the market at reasonable cost is another reason for selecting it for the present work.

References

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