LIGHT PATTERN RECOGNITION AND PROFILING USING MODIFIED CCD CAMERA

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronic Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

Dr Mumtaj Begam
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nurul Aireen Bt Mohd Yatim

ABSTRACT

The main objective of this project is to design an instrument, which enables the production of a profile of a pattern due to variation of light intensity. The light pattern recognition is obtained from the light intensity distribution profile. The light beam pattern recognition can be widely used in various applications such as profiling reflection of light from irregular surfaces, bar code intensity analysis and particles sizing for biological cells characterization. The light intensity distribution patterns can be observed using light-sensing element and the methodology behind the design requires designation of light pattern capturing device that gives analog signals at the output, which can be observed on an oscilloscope. These analog signals represent the voltage variation proportional to the light intensity distribution. The design of circuitry part is included in this report, which discusses the contribution of each circuit element towards the working of the prototype. At the end of this report, conclusion and recommendations are made to summarize up the overall project.

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude to my former supervisor, Dr Saeed-Ul Hassan Naqvi for his useful advices and meaningful knowledge throughout completing my Final Year Project under his supervision during the first semester. His guidance and support are the main factors that inspired me to complete the project within the specific time frame.

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LIST OF ABBREVIATIONS

CCD	Charge-Coupled Device
UV	Ultra violet
PCB	Printed Circuit Board
MAX	Maximum
MIN	Minimum
nm	nanometer

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Light is an electromagnetic radiation that is visible to human eye. The elementary particle that defines light is the photon. There are three basic parameters of light namely intensity which is a measure of brightness of light, frequency or wavelength which indicates the color of light and polarization which refers to the angle of electric field vector with respect to plane of incidence [1]. In this study the focus is on the method of analyzing light intensity distribution pattern on a light exposed area. A pattern is projected through an optical system by light exposure coming from a source.

The measure of light intensity depends on the image segment that is being analyzed. The inverse square law states that the light intensity reduces as the square of the distance it travels from the light source [2]. In other words, the intensity of light decreases as it travels longer distances. Since different images represent different intensity distribution of light, the applications of this study can include particles sizing, bar code intensity analysis, bacteria colony detection and others. In particles sizing, the multi-angle light detector is used to characterize the light scattered from biological cells [3]. This can be done due to different refractive index produced by different cells or particles. While in bar code intensity analysis, the light pattern distribution of bar code actually represents the distribution of data in terms of voltages.

Due to the distinct pattern of the light intensity coming from different shapes, the pattern can be profiled using appropriate method in a form of stream of electrical pulses of varying voltage or current.

1.2 Problem Statement

Digital cameras, optical image scanners, digital copiers and digital facsimile machines use Charge-Coupled Device (CCD) arrays to convert a visible image into an electronic form suitable for copying, storing, or processing by a computer. Particularly color photosensor arrays commonly have performance parameters that are characterized before product manufacturing. The parameters are commonly stored in non-volatile memory within imaging devices using the photosensor arrays. Similarly there is a need for electronic identification of light patterns by CCD arrays or any light-sensing element so that an imaging device can recognize a pattern. Therefore, by scanning the pattern it is possible to profile the pattern of an image segment. This could be done by scanning voltages or current as the measure of intensity distribution of that pattern.

1.3 Objectives and Scope of Study

1.3.1 Objectives

- To analyze the light intensity distribution through an image capture device for electronic identification in bar code analysis and bacteria colony detection
- To utilize the CCD array or other light sensor element incorporated with suitable circuitry
- To design and construct the electronic circuit in order to view the output stream of analog data on a display device

1.3.2 Scope of Study

The analysis of light intensity distribution or simply refers to the light pattern recognition is to be completed within the time frame given which is approximately 14 weeks. Resources for the project are obtained locally and the equipment used for the instrumentation is located within the Electrical and Electronic Laboratory of UTP academic building. In order to accomplish the project, literature research followed by selection method analysis, work planning and electrical parts designation is performed accordingly. These tasks have been planned in a sequential manner in order to produce a workable and feasible prototype.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Light-sensing elements

Light intensity from different light exposure is detected by the light-sensing element in order to recognize the intensity distribution pattern. In this project, light-sensing element is used to capture light intensity and convert the image to an electric signal that can be viewed on a display device as the measure of intensity distribution. Several types of light-sensing elements such as CCD array and Cadmium Sulfide Cell are described further below.

2.1.1 CCD Array

Charge-Coupled Device (CCD) array is an array of light sensitive cells. It is normally used in digital photography, photometry, optical and UV spectroscopy [4]. The operation of the array starts by sensing the intensity of light from an image projected on the array. Each cell acts as a capacitor and accumulates an electric charge proportional to the light intensity at that location. A control circuit causes each capacitor to transfer its contents to a circuit that refreshes the same capacitor and also transfer it to the output. The output charge is transferred into an amplifier that converts the charge into voltage. By repeating the process, the control circuit converts the entire contents of the array to a stream of varying voltages proportional to the received light.

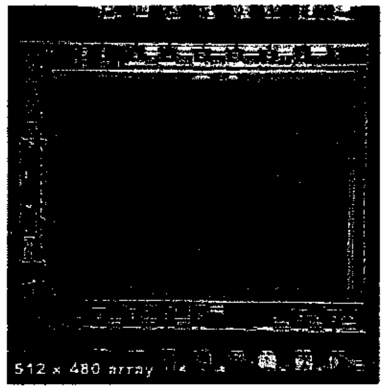

Figure 1 CCD array taken through a microscope at 10X power [5]

2.1.2 Cadmium Sulfide Cell

Cadmium Sulfide Cell, which is also known as Light Dependent Resistor (LDR) is a photoconductive photocell that is designed to sense light from 400nm to 700nm (refer Appendix B). Light dependent resistors, are available in a wide range of resistance values and packaged in a two-leaded plastic-coated ceramic header. The light-sensitive part of the LDR is a wavy of cadmium sulfide. Light energy that is captured on LDR triggers the release of extra charge carriers in the material, so that its resistance decreases as the level of illumination increases. LDR is widely used in applications such as automatic dimmers, ambient light detector, camera exposure, shutter controls and night light controls. This element features visible light response with a low cost and has a high reliability. In lighting control circuits, LDR is used as a dark sensor since it gives a low voltage when the LDR is exposed in the light and a high voltage when the LDR is in the shade. Diagram below shows a photoconductive photocells (LDR) and its circuit symbol.

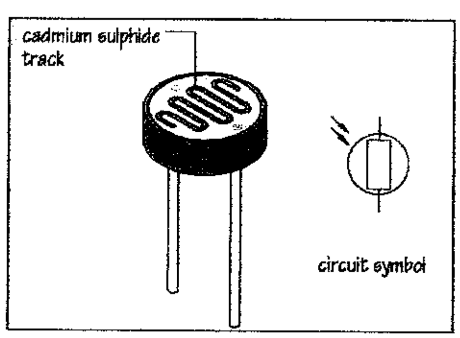

Figure 2 Cadmium Sulfide Cell or LDR [6]

2.2 The concept of light intensity

The spectrum of visible light or spectrum of visible electromagnetic radiation lies between 400nm and 700nm. Unit for measuring light is candela, which is the luminous intensity of a source that emits monochromatic radiation of frequency 540×10^{12} Hz [7]. The human eye has a varying sensitivity from blue to red light. Thus, the frequency chosen is at which the eye is most sensitive, normally at the corresponding wavelength of 555nm. Luminous emission is not the same as the perceived brightness of a source because the brightness is defined as the energy within a given solid angle and is independent of the distance to the measuring instrument.

The measurement of luminous intensity from a light source requires relative sensitivity of the eye to different wavelength. Figure 3 below shows a curve that defines the relationship between human sensation of light and the physical concept of energy. The curve is obtained by averaging results from experiments that has been standardized as an essential component in the quantitative description of light. In other words, the curve shows that the highest luminous efficiency is at approximately 555nm that indicates that human eye is at its highest sensitivity. Whereas at lower end and higher end of wavelength; 400nm and 700nm respectively, the efficiency is lower that indicates that human eye is at its lowest sensitivity.

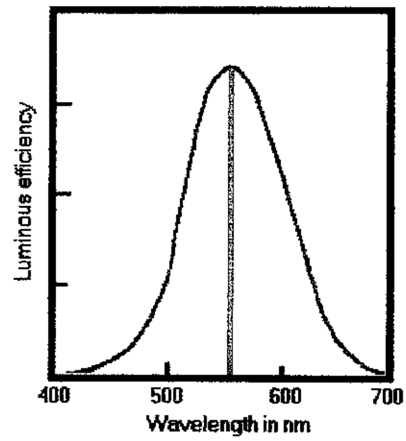

Figure 3 Luminous efficiency v/s wavelength curve [7]

2.3 Voltage Divider Theorem

The voltage divider rule is a way to determine the output voltage of two impedances connected in series. It can be used with resistive, inductive or capacitive elements. However, the method of calculating the output voltage is different according to the type of circuit elements. In this project, the voltage divider is concentrating on using resistive elements to predict the output voltage from the divider given the input supply voltage and values of the two resistors in the divider. Besides, the changes of the output voltage can be determined when any of the resistance value changes. Overall, voltage divider theorem is a very useful tool for circuit analysis and design. In voltage divider, two resistors are connected in series as shown in the Figure 4 below. An input voltage is applied and the output voltage is measured across one of the two resistors. The output voltage V_o is related to V_i as follows:

$$v_0 = v_i\left(\frac{R_2}{R_1 + R_2}\right) \text{...........Equation (1)}$$

If no external connection to Vo, it is simply a series connection and the same current flow through both resistors. Thus, according to Ohm's Law, the ratio of voltages across these resistors will be equal to the ratio of the resistance values themselves.

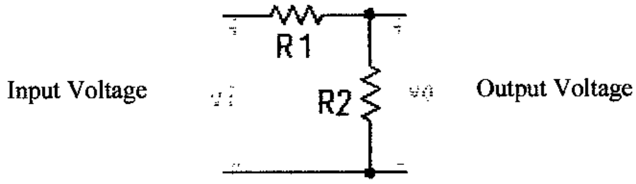

Figure 4 Voltage divider circuit

2.4 Light sensor device

Light sensor finds its way into a host of interesting applications. Presently, there are many other applications for light sensors, such as flame detectors, security systems, lighting control and robotics. In a smoke detector, a light sensor can be used to measure the amount of light transmitted by a known light source, such as an LED, through the air inside the sensor assembly. When the air becomes smoky, the amount of light received by the sensor changes. Once the light change goes above a preset threshold, it indicates that there is a fire in the building. Thus, a horn is activated. Similarly, a light sensor in a camera measures the amount of light that the film will be exposed to. Once the amount of light is known, the proper lens aperture can be calculated to ensure that the picture is taken with the proper amount of exposure.

Photodiodes and phototransistors are the most popular and low cost light sensors. These devices produce current and voltage outputs as a function of light intensity. The operating range of such devices varies depending on the manufacturer. Many of these sensors are equipped with built in lenses that has been tuned to a particular wavelengths. Therefore, they are most effective for detecting or measuring light with those specific wavelengths. In order to obtain the best performance, the voltage across the sensor needs to be held constant during measurement. Depending on each different application, system calibration and linearization may be required. The optimum measurement depends on the light sensor, amount of light used in the application, and the internal voltage-reference setting.

CHAPTER 3
METHODOLOGY / PROJECT WORK

3.1 Project Work

The project follows the procedure indicated in the flow chart shown in Figure 5. It consists of five major stages starting with literature research followed by selection of hardware and software, design, testing and evaluation and ending with the implementation.

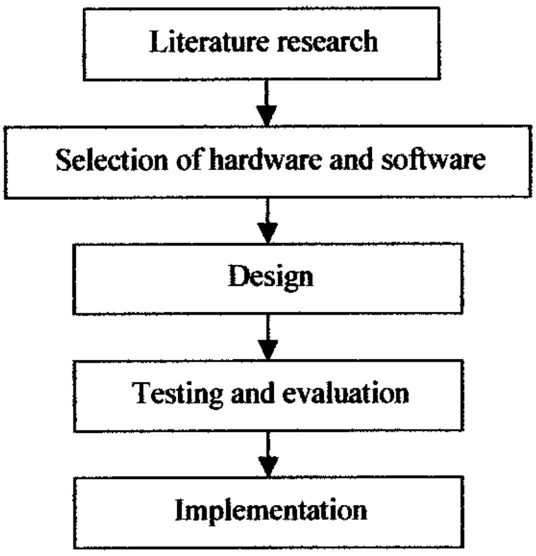

Figure 5 Methodology flow diagram

3.2 Planning

Useful information is gained through the planning process and it helps a lot in the progress of the project design. The literature review has been divided into three main parts; a modified CCD array architecture, the light sensor element and the concept of light intensity. Through these divisions, it is much easier to design and fulfill the project requirement.

3.3 The basic design

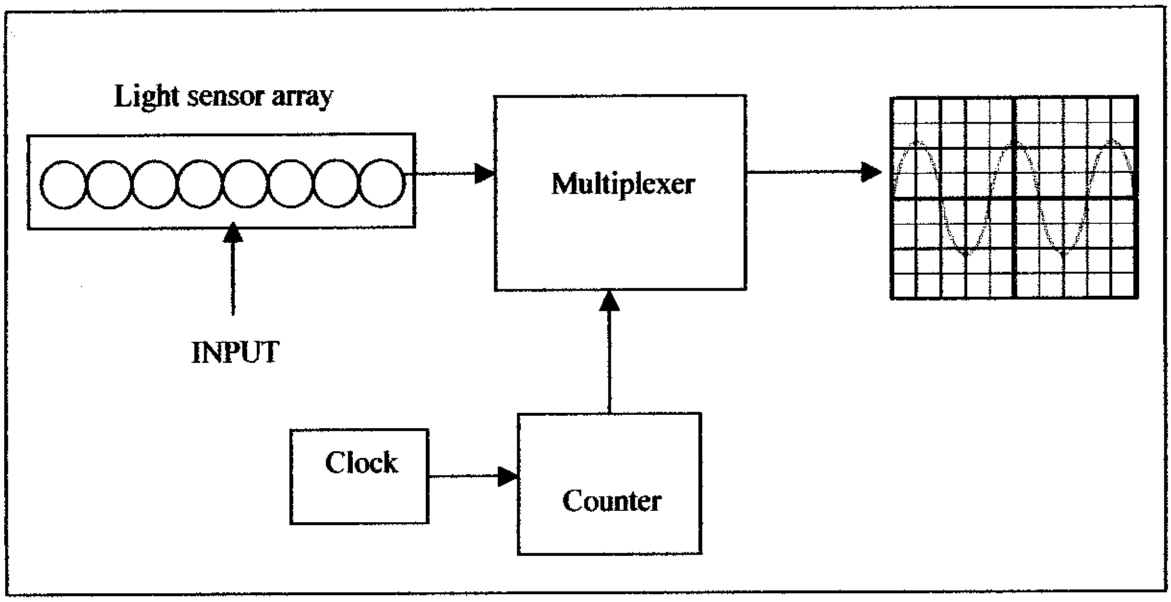

Figure 6 Block diagram of light intensity measurement

Figure 6 shows the block diagram of light intensity distribution analysis system. The electrical circuitry of the project consists of light sensor element as light capturing device, multiplexer including counter and clock and an oscilloscope as the display device. The input of light sensor element is a pattern of light of image segment having duration as low as several nanoseconds. A multiplexer is a device that has multiple inputs and only one output. It forwards one of the input's content to the output based on the binary value of the counter. In this project, multiplexer is used in the circuitry as to combine several analog signals from the light sensor elements and output them to an oscilloscope. A counter that is attached to a clock circuit controls the synchronization of the multiplexer.

3.3.1 Clock

The typical 555 timer (refer Appendix C) is used in the design circuit as it can be configured as an astable multivibrator or a rectangular wave generator. In this project, astable multivibrator is chosen as it oscillates between two states without any external triggering. Figure 7 shows a basic 555 timer connected as an astable multivibrator acting as clock or oscillator to the overall circuit.

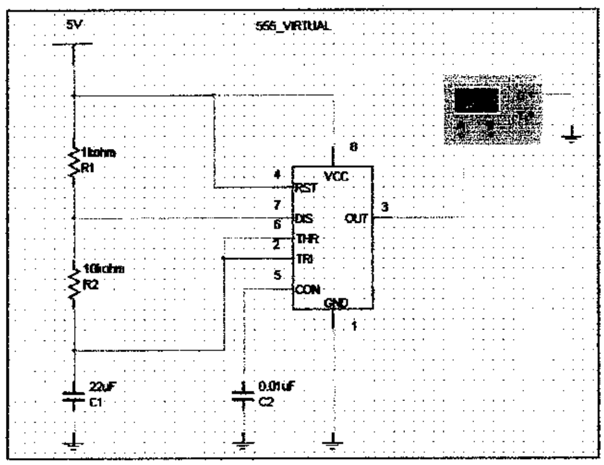

Figure 7 The 555 timer connected as an oscillator

3.3.2 Counter

The 74HC190, an up synchronous decade counter (refer Appendix D) is chosen to be used in the circuit as it is capable of progressing in one direction through a certain sequence. The level of the up enable input determines the direction of the count. When the input is HIGH, the counter counts down and it counts up when input is LOW. The *MAX / MIN* output produces a HIGH pulse when the terminal count nine (1001) is reached in the UP mode or when the terminal count zero (0000) is reached in the DOWN mode. Figure 8 shows a 74HC190 up synchronous decade counter connected between oscillator and multiplexer.

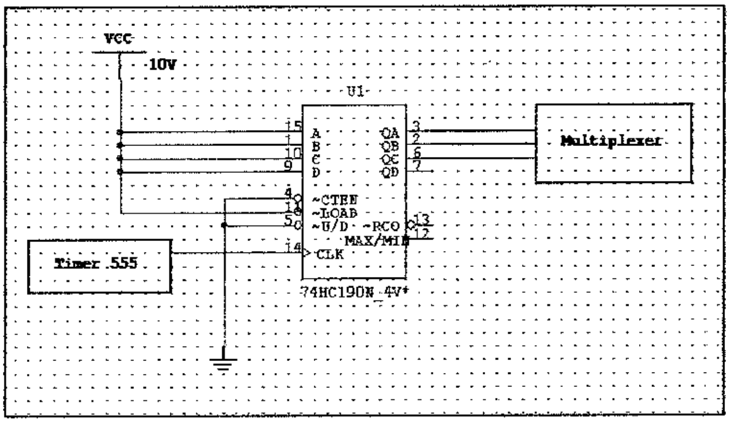

Figure 8 74HC190 : up synchronous decade counter

3.3.3 Multiplexer

A multiplexer is a device that allows information from several sources to be routed into a single line for transmission over the line to a common destination. It has several data-input lines and a single output line. It also has data-select inputs, which permit digital data on one of the inputs to be switched to the output line. An 8-input data multiplexer with 3 data-selectors (refer Appendix E) is used in the design circuit. In this circuit an analogue multiplexer is used whose input pins are connected to light sensor elements which are photodiode while the data selectors are connected to the counter. The output of the multiplexer was connected to a display device, which is an oscilloscope.

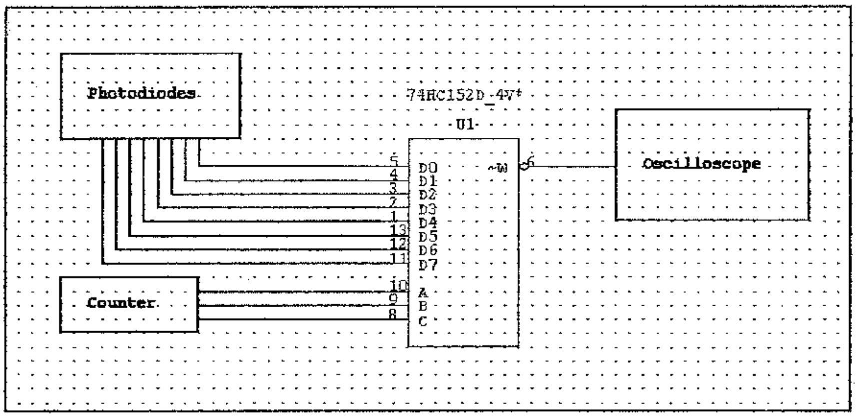

Figure 9 8-input multiplexer

3.4 Hardware and Software Requirement

The circuit design was carried out using appropriate hardware and software as listed below.

3.4.1 List of electronic components used in hardware

- Timer 555 (oscillator)
- Up synchronous decade counter
- 8-input multiplexer
- Light-sensing element
- Oscilloscope
- Resistors
- Capacitors

3.4.2 List of Software used for design and simulation

- Multisim Electronics Workbench (Simulation)
- Eagle (PCB)

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Description of 555 Oscillator circuit

A 555 timer operates as an astable multivibrator, which is a nonsinusoidal oscillator. Initially, as the power is turned on, the capacitor (C1) is uncharged and thus the trigger voltage (see Figure 7) is at 0 V. This causes the output of comparator at pin 2 to be high and the output of comparator at pin 6 to be low which force the output of the latch and keeping the internal transistor in off state. As C_1 begins charging through R_1 and R_2 until it reaches 1/3 of V_{cc}, the comparator at pin 2 switches to low output state and when the capacitor voltage reaches 2/3 of V_{cc}, comparator at pin 6 switches to high output state. This resets the latch and causing the internal transistor to turn on. The sequence creates a discharge path for the capacitor through R_2 and the internal transistor.

When the capacitor begins to discharge comparator at pin 6 is at low output state. At the point where the capacitor discharges down to 1/3 of V_{cc}, comparator at pin 2 switches to high output state. This sets the latch and turns off the capacitor. The entire process repeats as another charging cycle begins [14].

4.1.1 Output Frequency calculation

The components R_1 (1kΩ), R_2 (10kΩ) and C_1 (22uF) form the timing network that sets the frequency of the oscillation is calculated by the following equation.

$$f = \frac{1.44}{(R_1 + 2R_2)C_1} \quad \text{............Equation (2)}$$

$$= \frac{1.44}{(1k\Omega + 2(10k\Omega))22\mu F}$$

$$= 3.12Hz$$

4.1.2 Pulse width and Duty Cycle calculations

The result of the oscillator is a rectangular wave output whose duty cycle depends on the values of R_1 and R_2. Therefore, the time for which the output is high, t_H and capacitor C_1 takes to charge from 1/3 V_{cc} to 2/3 V_{cc} is calculated below.

$$t_H = 0.7(R_1 + R_2)C_1 \quad \text{............Equation (3)}$$

$$= 0.7(1k\Omega + 10k\Omega)22\mu F$$

$$= 0.1694s$$

The time for which the output is low is t_L and capacitor C_1 takes to discharge form 2/3 V_{cc} to 1/3 V_{cc} is calculated below.

$$t_L = 0.7R_2C_1 \quad \text{............Equation (4)}$$

$$= 0.7(10k\Omega)(22\mu F)$$

$$= 0.154s$$

Thus, the period, T of the output waveform is the sum of t_H and t_L which is the reciprocal of frequency of the oscillation.

$$\begin{aligned} T &= t_H + t_L \qquad \text{.............Equation (5)} \\ &= 0.1694s + 0.154s \\ &= 0.3234s \end{aligned}$$

The duty cycle, which is the ratio of t_H to T, is calculated by the following equation.

$$\begin{aligned} DutyCycle &= \frac{R_1 + R_1}{R_1 + 2R_2} \times 100\% \qquad \text{.............Equation (6)} \\ &= \frac{1k\Omega + 10k\Omega}{1k\Omega + 2(10k\Omega)} \times 100\% \\ &= 52.38\% \end{aligned}$$

4.2 Description of Counter circuit

The 74HC190, an up synchronous decade counter is chosen to be used in the design circuit. Since the input of the multiplexer is 8, thus it needs a counter, which provides 3-bit binary sequence. Table 1 shows the complete up sequence for a 3-bit binary counter. The arrows indicate the state-to-state movement of the counter for its UP mode of operation. The operation of the counter circuit was well functioned where the output shows an up sequence of 8 clock pulse that lights ON and OFF following the 3-bit binary counter as shown in the above table. The counter counts continuously provided that an oscillator circuit is connected at the clock input pin (CP) of the counter. 74HC190 counter preset to seven (0111) and then go through a count-up sequence followed by a count-down sequence. The MAX/MIN output is HIGH when the counter is in either all 0s state (MIN) or the 1001 state (MAX) [14].

Clock Pulse	**UP**	**Q1**	**Q2**	**Q3**
0		0	0	0
1		0	0	1
2		0	1	0
3		0	1	1
4		1	0	0
5		1	0	1
6		1	1	0
7		1	1	1

Table 1 Up sequence for a 3-bit binary counter

4.3 Description of multiplexer circuit

4.3.1 Parallel-to-Serial Data Conversion

Parallel-to-serial conversion is accomplished by the use of a counter to provide a binary sequence for the data-select inputs of a data selector. Essentially, the parallel data bits on the multiplexer inputs are converted to a serial data bits on the single transmission line. The outputs of the modulus-8 counter are connected to the data-select inputs of an 8-bit multiplexer. When the first byte (8-bit group) of parallel data is applied to the multiplexer inputs, the counter goes through a binary sequence from 0 to 7 where each bit is sequentially selected and passed through the multiplexer to the output line. After 8 clock pulses, the data byte has been converted to a serial format and sent out on the transmission line. As the counter recycles back to 0, the next byte is applied to the data inputs and is sequentially converted to serial form as the counter cycles through its 8 states. The process continues repeatedly as each parallel byte is converted to a serial byte.

4.4 Light-sensing element

According to voltage divider theorem, the changes of LDR are the output, which need to be displayed on the oscilloscope as representation of light intensity distribution captured on the surface on LDR. Figure 10 below shows connections of light-sensing elements on multiplexer circuitry where the voltage drop across LDR is taken as the input of the multiplexer.

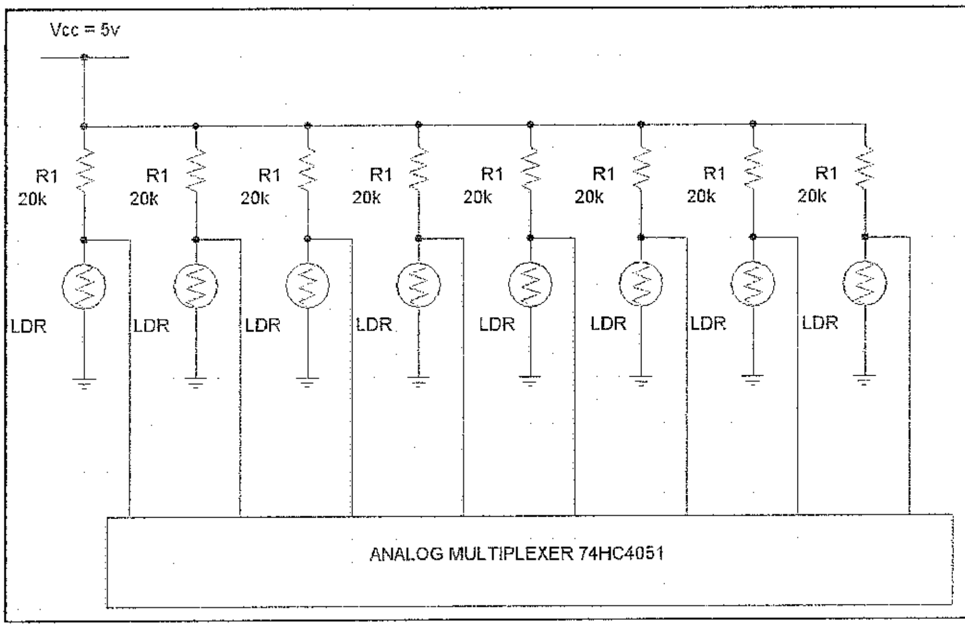

Figure 10 Input of analog multiplexer

4.4.1 Discussions

An experiment has been conducted in order to obtain the optimum value of fixed resistor (R_1). The result of the experiment is showed in Table 2. The method used in the calculation is the voltage divider theorem where the output of voltage drop across LDR is measured while the upper resistor (R_1) was varied from 200Ω to 2MΩ. The circuit is supplied with 5V of power supply. Each output voltage was measured using multimeter and also calculated numerically in order to observe the validity of the measurement. The light-sensing element is called a dark sensor since it gives a high Vout when it is fully covered and low Vout in constant light. From the observation, test resistor of value 20kΩ gave the highest voltage changes between constant light and dark condition. Therefore, it is used as the fixed resistor in order to make the light sensor device most sensitive to changes in illumination.

Test Resistor	Vout in the light		Vout in the dark		Voltage change	
	Measured (v)	Calculated (v)	Measured (v)	Calculated (v)	Measured (v)	Calculated (v)
200Ω	4.492	4.545	4.96	4.990	0.468	0.445
2kΩ	2.555	2.500	4.88	4.870	2.325	2.370
20kΩ	0.456	0.455	3.74	3.950	3.284	3.496
200kΩ	0.052	0.050	2.08	1.364	2.029	1.315
2MΩ	0.005	0.005	0.18	0.180	0.175	0.175

Table 2 Voltage changes vs test resistor

4.5 Project verification

The circuit was tested and evaluated with 5V input voltage supply in order to observe the output voltage that corresponds to the light intensity across LDR. The changes of the output voltage were measured during dark and constant light condition. Table below shows the result output.

LDR	Dark (Vout)		Constant light (Vout)	
	Oscilloscope(v)	Multimeter(v)	Oscilloscope(v)	Multimeter(v)
S1	4.80	4.95	2.30	2.35
S2	4.80	4.91	2.30	2.01
S3	4.80	4.83	2.30	2.33
S4	4.80	4.90	2.30	2.21
S5	4.80	4.90	2.30	2.28
S6	4.80	4.88	2.30	2.11
S7	4.80	4.93	2.30	2.38
S8	4.80	4.95	2.30	2.08

Table 3 Light intensity in terms of output voltages

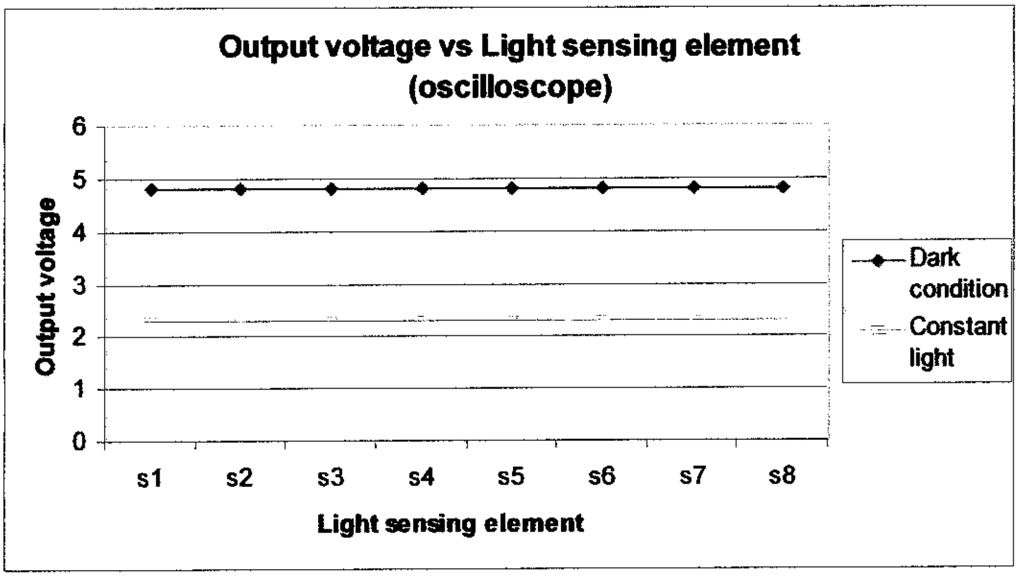

Figure 11 Measurement of light intensity at Oscilloscope

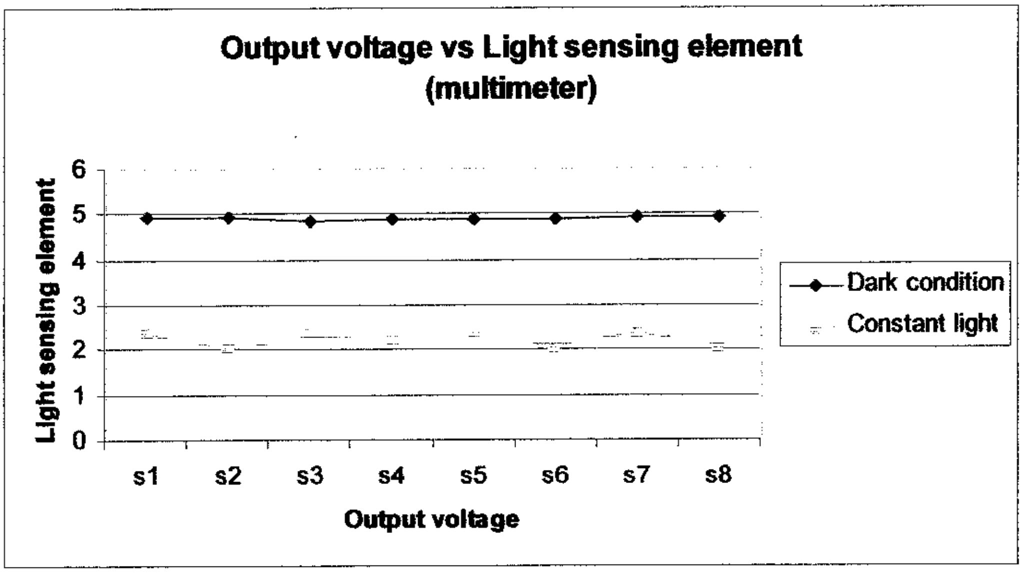

Figure 12 Measurement of light intensity at Multimeter

4.5.1 Discussions

According to the graphs, in dark conditions, the voltage is relatively large because the sensor dark resistance is high. In constant light, the voltage is relatively small because the sensor dark resistance is low. These indicate that the value of light sensing element changes as the incident light intensity that falls upon it changed. Prior to hypothesis, it is desired to have a sensor circuit that give a large signal that is close to the voltage input (5V) as the sensor is exposed to dark condition. In the other hand, it will give smaller signal that is close to 0V when the sensor is in a constant light. The output waveform on the oscilloscope would only goes higher or lower in terms of voltages as the LDR receive different light intensity.

4.6 Complete proposed circuit design

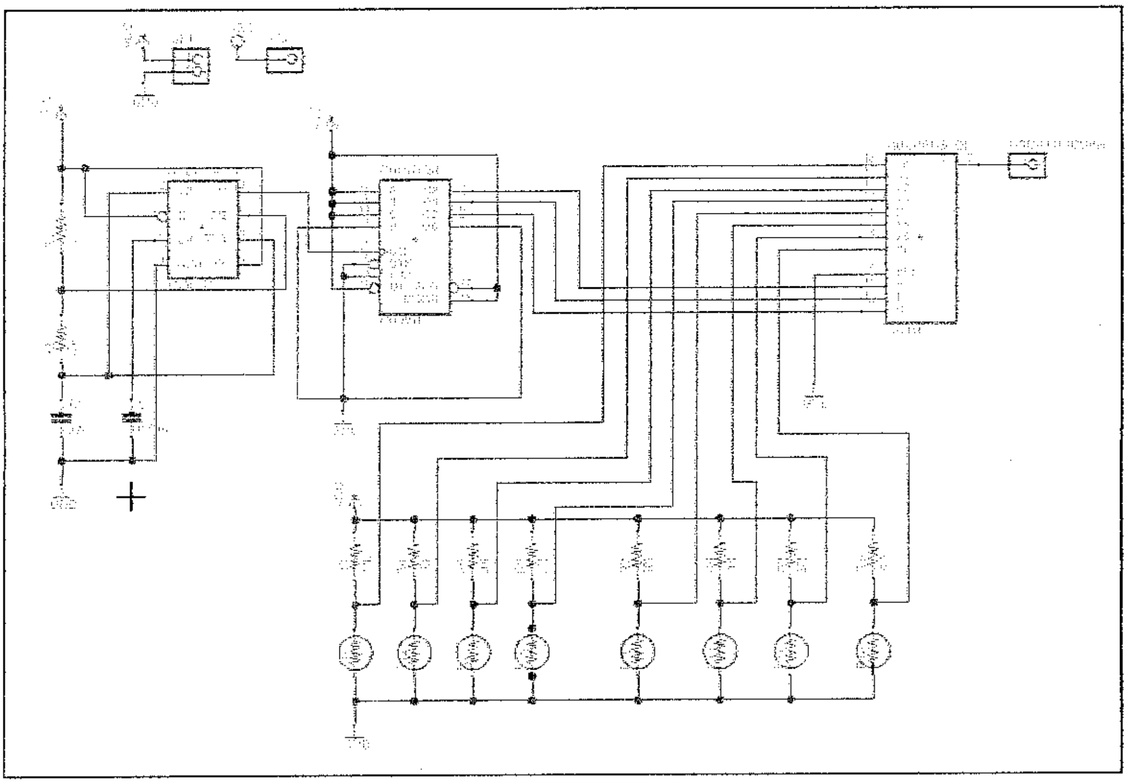

Figure 13 Schematic drawing of the complete circuit

4.6.1 Descriptions on circuit design

Figure 13 shows the schematic drawing for the entire circuit that has been designed. Basically, it consists of oscillator circuit that generates clock pulse, which is connected to the counter. The counter that provides the sequence for data selection is connected to the multiplexer. Simultaneously, the multiplexer is also attached to an array of light-sensing element. The output of the multiplexer is observed on the display device, which is an oscilloscope. The output can be seen as the variation of voltage proportional to the light intensity distribution falling on the light-sensing element.

4.7 Prototype model

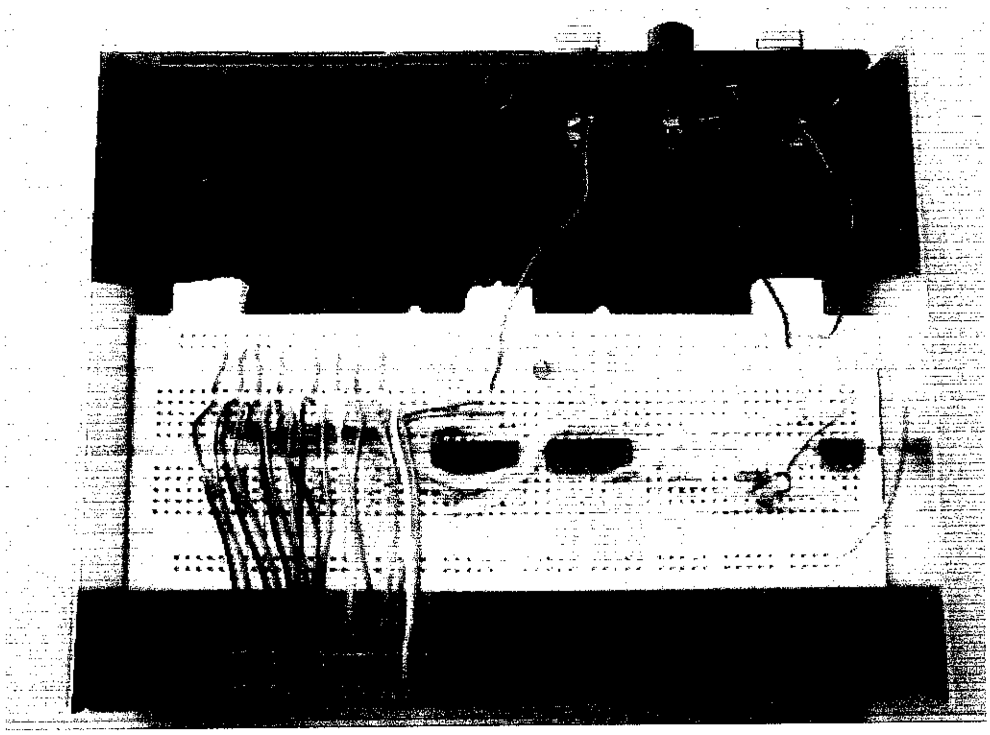

Figure 14 Complete prototype model of the project

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Light pattern recognition is a result of light intensity analysis observed by light-sensing elements. The image intensity is converted to analog signals for parallel-to-serial data conversion, which is also known as multiplexing. Light-sensing elements has been utilized in this project incorporated with oscillator circuit, up synchronous counter and analog multiplexer that represent the modification of CCD camera. The methodology of scanning voltages across a horizontal line of an image segment is the focus of study on this project. Light intensity distribution patterns from the particular image segment captured by the light-sensing elements are observed on a display device. These patterns represent the electronic identification for applications in bar code analysis, bacteria colony detection and others. Thus, light ranges from 400nm to 700nm in wavelength can be profiled using the proposed methodology. The prototype of hardware has been constructed and it is working according to the specifications. The testing and evaluation of the project work has been done and the graphs obtained indicate the results of the testing and verification of the project.

5.2 Recommendation

For further improvement of the project, utilization of analog shift register that allows each portion of the captured image to be addressed in storage elements might be needed for storing and processing purposes. Besides, the light distribution pattern can be observed on other display device such as an xt-chart recorder for data acquisition system as it has larger display scale. In addition, this project could be further focused into a specific industrial use. Therefore, by enhancing the prototype model, the performance of this device would also be improved and further to be used as a feasible light intensity distribution analysis device.

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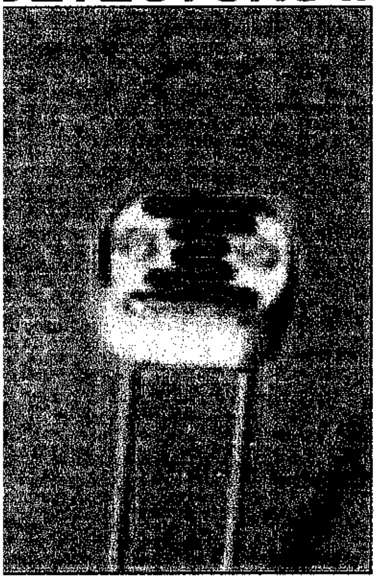
APPENDICES

APPENDIX A

DATASHEET : CADMIUM SULFIDE CELL

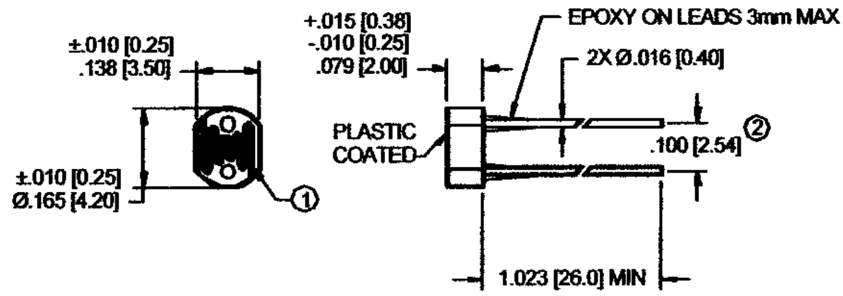
PHOTONIC DETECTORS INC. Cadmium Sulfoselenide (CdS) Photoconductive Photocells

Type PDV-P9XXX-X



PACKAGE DIMENSIONS INCH [mm]

INDUSTRY EQUIVALENTS: VT900 & NSL5152



PLASTIC COATED CERAMIC PACKAGE

1. PHOTOCELL "GRID" PATTERN CAN VARY. PDI RESERVES THE RIGHT TO CHANGE AND MIX GRID PATTERNS.
2. DIMENSION CONTROLLED AT BASE OF CERAMIC HEADER PACKAGE.

EATURES

- Visible light response
- Sintered construction
- Low cost
- High Reliability

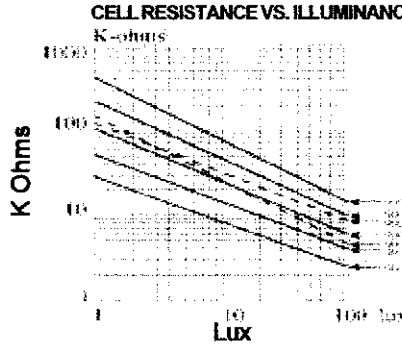
DESCRIPTION

PDV-P9XXX-X are (CdS) photoconductive photocells designed to sense light from 400 nm to 700 nm. As light dependent resistors, they are available in a wide range of resistance values. They are packaged in a two leaded plastic-coated ceramic header.

APPLICATIONS

- Camera exposure
- Low light level
- Shutter controls
- Night light controls

CELL RESISTANCE VS. ILLUMINANCE



BSOLUTE MAXIMUM RATING (TA=25°C unless otherwise noted)

SYMBOL	PARAMETER	MIN	MAX	UNITS
V_{PK}	Applied Voltage		150	V dc
$P_{diss\ pdut}$	Continuous Power Dissipation		90	mW/°C
T_{stg} & T_o	Operating Temperature Range & Storage	-30	+75	°C
Ts	Soldering Temperature*		+260	°C

200 inch (5 mm) from bottom of header for 3 secs max with heat sink

LECTRO-OPTICAL CHARACTERISTICS TA=25°C (2 HOURS LIGHT ADAPT, MIN)***

MODEL NO.	CELL RESISTANCE** (Ohms)				SENSITIVITY	SPECTRAL PEAK	RESPONSE TIME @10 Lux	
	10 Lux @2856K		DARK		LOG(R100)-LOG(R10) / LOG(E100)-LOG(E10)	(nm)	RISE TIME (ms)	FALL TIME (ms)
	MIN (KΩ)	MAX (KΩ)	MIN (MΩ)	SEC	(λ TYP)	TYP	TYP	TYP
PDV-P9001	4	11	0.3	10	0.65	520	60	25
PDV-P9002	9	20	0.5	10	0.6	520	60	25
PDV-P9002-1	11	20	0.5	10	0.7	520	60	25
PDV-P9003	16	33	1	10	0.8	520	60	25
PDV-P9003-1	23	33	1	10	0.85	520	60	25
PDV-P9004	27	60	2	10	0.85	520	60	25
PDV-P9005	50	94	2.5	10	0.9	520	60	25
PDV-P9005-1	48	140	20	10	0.9	520	60	25

formation in this technical data sheet is believed to be correct and reliable. However, no responsibility is assumed for possible inaccuracies or omission. Specifications are subject to change without notice. ** Photocells are light adapted at 100 to 500 Lux. *** Photocells are tested at 2856°K at a 10 Lux light level. Resistance values are for reference only.

[FORM NO. 100-PDV-P9001 REV A]

APPENDIX B

DATASHEET : OSCILLATOR

Timer

555

FEATURES

- Turn-off time less than 2µs
- Max. operating frequency greater than 500kHz
- Timing from microseconds to hours
- Operates in both astable and monostable modes
- High output current
- Adjustable duty cycle
- TTL compatible
- Temperature stability of 0.005% per °C

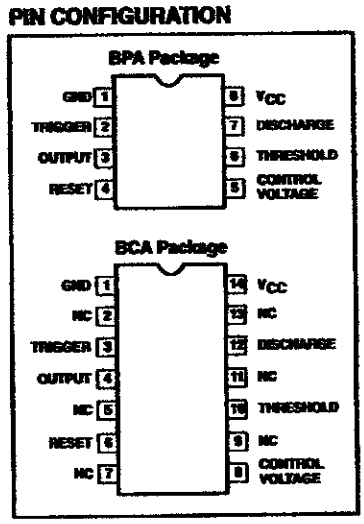
APPLICATIONS

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Missing pulse detector

DESCRIPTION

The 555 monolithic timing circuit is a highly stable controller capable of producing accurate time delays, or oscillation. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For a stable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output structure can source or sink up to 200mA.

PIN CONFIGURATION

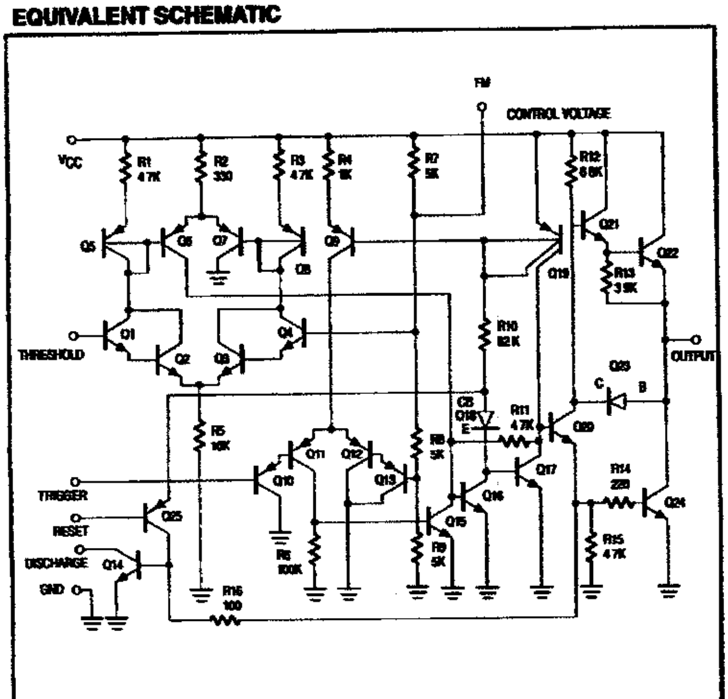


ORDERING INFORMATION

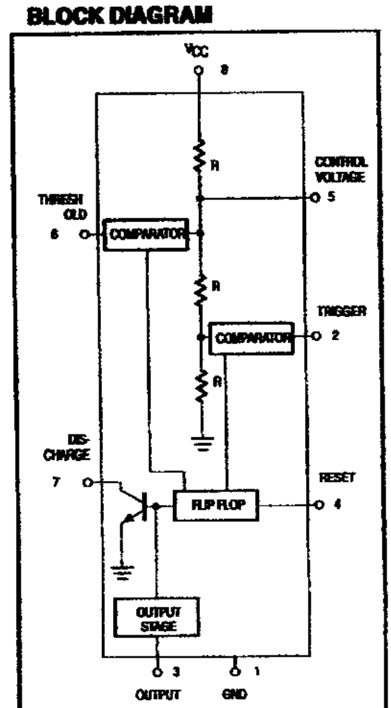
DESCRIPTION	ORDER CODE	PACKAGE DESIGNATOR*
14-Pin Ceramic DIP	555/BCA	GDIP1-T14
8-Pin Ceramic DIP	555/BPA	GDIP1-T8

* MIL-STD 1835 or Appendix A of 1995 Military Data Handbook

EQUIVALENT SCHEMATIC



BLOCK DIAGRAM



Timer   555

ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING[1]	UNIT
V_{CC}	Supply voltage	+18	V
P_D	Power dissipation	600	mW
T_{STG}	Storage temperature range	-65 to +150	°C

DC ELECTRICAL CHARACTERISTICS

V_{CC} = +5V to V_{CC} = +15V, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	T_{amb} = +25°C MIN	TYP	MAX	T_{amb} = -55°C, +125°C MIN	TYP	MAX	UNIT
V_{CC}	Supply voltage		4.5		18	4.5		18	V
I_{CC}	Supply current (low state)[2]	V_{CC} = 5V, $R_L = \infty$		3	5			6	mA
		V_{CC} = 15V, $R_L = \infty$		10	12			14	mA
	Timing error (monostable)	R_A = 2kΩ to 100kΩ							
t_M	Initial accuracy[3]	C = 0.1µF		0.5	2.0			2.5	%
$\Delta t_M/\Delta T$	Drift with temperature[7, 8]							100	ppm/°C
$\Delta t_M/\Delta V_S$	Drift with supply voltage			0.05	0.2			0.25	%/V
	Timing error (astable)	R_A, R_B = 1kΩ to 100kΩ							
t_A	Initial accuracy[3]	C = 0.1µF		4	6			10.0	%
$\Delta t_A/\Delta T$	Drift with temperature[7]	V_{CC} = 15V						500	ppm/°C
$\Delta t_A/\Delta V_S$	Drift with supply voltage[9]			0.15	0.6			1.5	%/V
V_C	Control voltage level	V_{CC} = +15V	9.6	10.0	10.4	9.6		10.4	V
		V_{CC} = +5V	2.9	3.33	3.8	2.9		3.8	V
V_{TH}	Threshold voltage	V_{CC} = +15V	9.4	10.0	10.6	9.4		10.6	V
		V_{CC} = +5V	2.7	3.33	4.0	2.4		4.0	V
I_{TH}	Threshold current[4]	V_{TH} = 10.6V		0.1	0.25			0.35	mA
V_{TRIG}	Trigger voltage	V_{CC} = +15V	4.8	5.0	5.2	4.5		5.5	V
		V_{CC} = +5V	1.45	1.67	1.9	1.5		2.2	V
I_{TRIG}	Trigger current	V_{TRIG} = 0V		0.5	0.9			2.0	µA
V_{RESET}	Reset voltage[5]		0.3		1.0	0.1		1.3	V
I_{RESET}	Reset current	V_{RESET} = 0.4V		-0.1	-0.4			-0.6	mA
I_{RESET}	Reset current	V_{RESET} = 0V		-0.4	-1.0			-1.2	mA
V_{OL}	Output voltage (low)[10]	V_{CC} = +15V							
		I_{SINK} = 10mA		0.1	0.15			0.25	V
		I_{SINK} = 50mA		0.4	0.5			0.70	V
		I_{SINK} = 100mA		2.0	2.2			2.6	V
		V_{CC} = +5V							
		I_{SINK} = 8mA		0.1	0.25			0.43	V
		I_{SINK} = 5mA		0.05	0.2			0.38	V
V_{OH}	Output voltage (high)[10]	V_{CC} = +15V							
		I_{SOURCE} = 100mA	13.0	13.3		12.5			V
		V_{CC} = +5V							
		I_{SOURCE} = 100mA	3.0	3.3		2.6			V
I_D	Discharge leakage current			20	100			500	nA

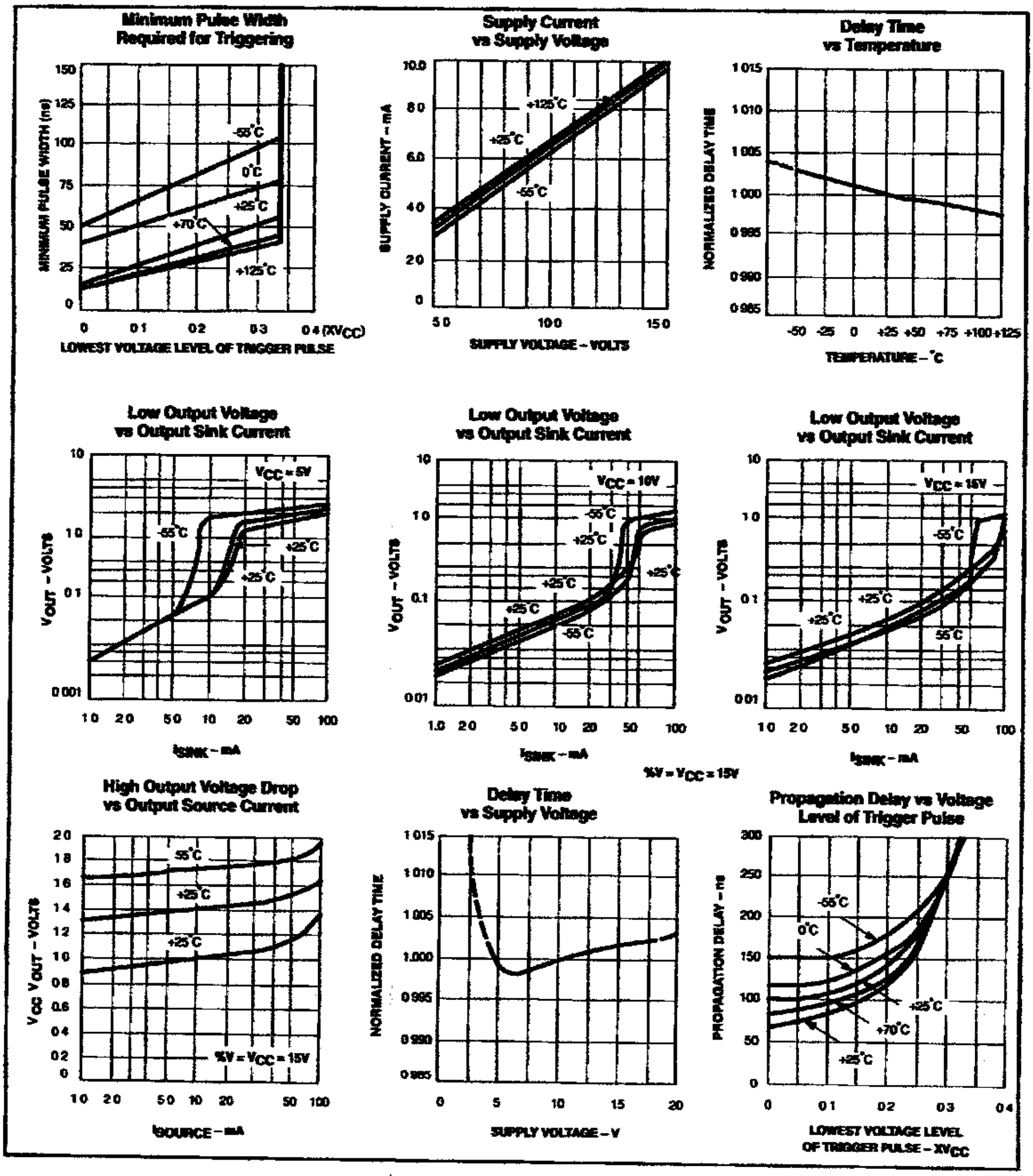
7AC ELECTRICAL CHARACTERISTICS

V_{CC} = +5V, V_{CC} = +15V, unless otherwise specified.

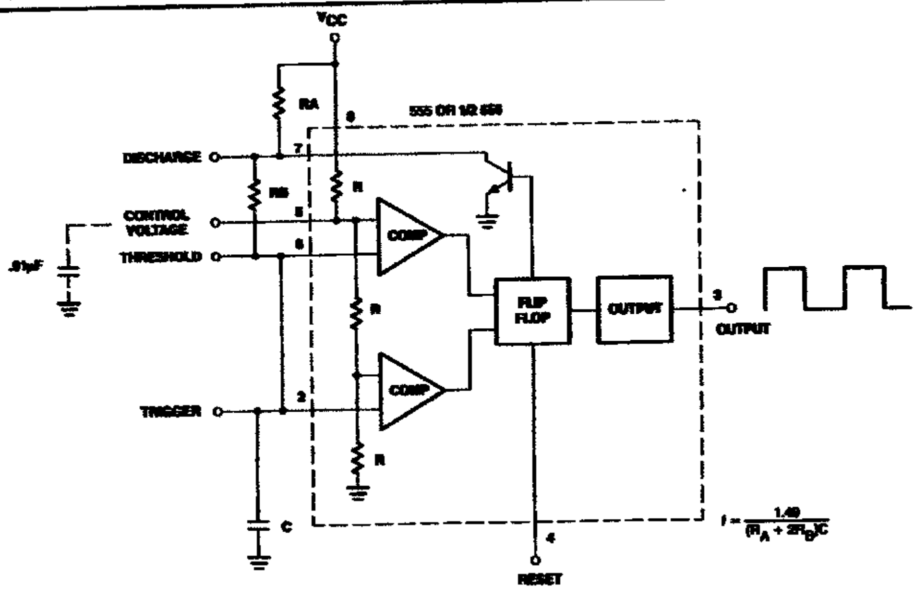
SYMBOL	PARAMETER	TEST CONDITIONS	T_{amb} = +25°C			T_{amb} = -55°C, +125°C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
t_{OFF}	Turn-off time[6, 7]	$V_{RESET} = V_{CC}$		0.5	2.0				µs
t_R t_F	Rise time of output[7] Fall time of output[7]			100 100	200 200				ns ns

NOTES:
1. Operation beyond the limits in this table may impair the useful life of the device.
2. Supply current when output high typically 1mA less.
3. Tested at V_{CC} = +5V and V_{CC} = +15V.
4. This will determine the max. value of $R_A + R_B$, for 15V operation, the max. total R = 10MΩ, and for 5V operation, the max. total R = 3.4MΩ.
5. Specified with trigger input high.
6. Time measured from a positive going input pulse from 0 to 0.8 X V_{CC} into the threshold to the drop from high to low of the output. Trigger is tied to threshold.
7. This parameter is guaranteed, but not tested.
8. Testing performed at R_A = 100kΩ only.
9. Testing performed at $R_A = R_B$ = 1kΩ only.
10. For long term static operation, derate the sink and source currents to 50mA maximum.

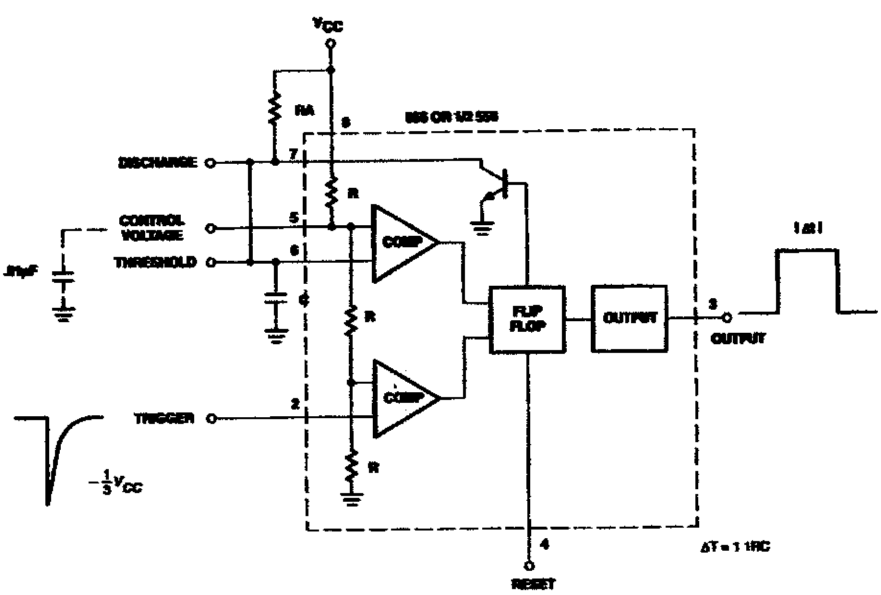
TYPICAL PERFORMANCE CHARACTERISTICS



TYPICAL APPLICATIONS



Astable Operation



Monostable Operation

APPENDIX C

DATASHEET : UP/DOWN PRESETTABLE SYNCHRONOUS BCD DECADE COUNTER

Presettable synchronous BCD decade up/down counter

74HC/HCT190

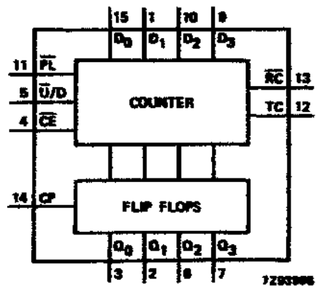


Fig.4 Functional diagram.

FUNCTION TABLE

OPERATING MODE	INPUTS					OUTPUTS
	$\overline{PL}$	$\overline{U}/D$	$\overline{CE}$	CP	D_n	Q_n
parallel load	L L	X X	X X	X X	L H	L H
count up	H	L	I	↑	X	count up
count down	H	H	I	↑	X	count down
hold (do nothing)	H	X	H	X	X	no change

TC AND RC FUNCTION TABLE

INPUTS			TERMINAL COUNT STATE				OUTPUTS	
$\overline{U}/D$	$\overline{CE}$	CP	Q_0	Q_1	Q_2	Q_3	TC	$\overline{RC}$
H	H	X	H	X	X	H	L	H
L	H	X	H	X	X	H	H	H
L	L	‾‾|_|‾‾	H	X	X	H	‾‾|_	‾‾|_|‾‾
L	H	X	L	L	L	L	L	H
H	H	X	L	L	L	L	H	H
H	L	‾‾|_|‾‾	L	L	L	L	‾‾|_	‾‾|_|‾‾

Notes

1. H = HIGH voltage level
   L = LOW voltage level
   I = LOW voltage level one set-up time prior to the LOW-to-HIGH CP transition
   X = don't care
   ↑ = LOW-to-HIGH CP transition

   ‾‾|_|‾‾ = one LOW level pulse
   ‾‾|_ = TC goes LOW on a LOW-to-HIGH CP transition

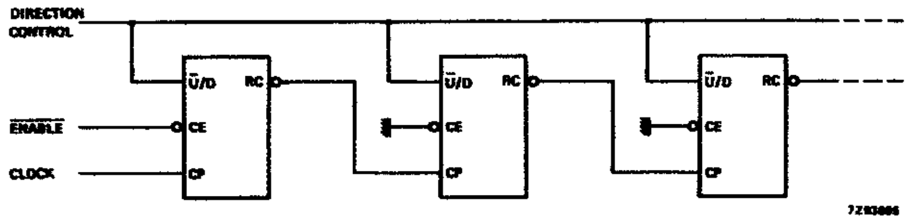


Fig.5 N-stage ripple counter using ripple clock.

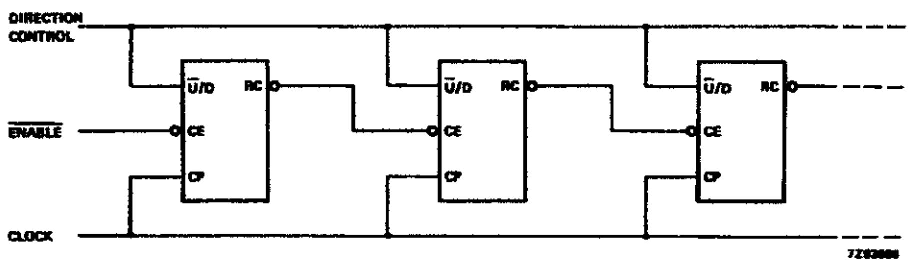


Fig.6 Synchronous n-stage counter using ripple carry/borrow.

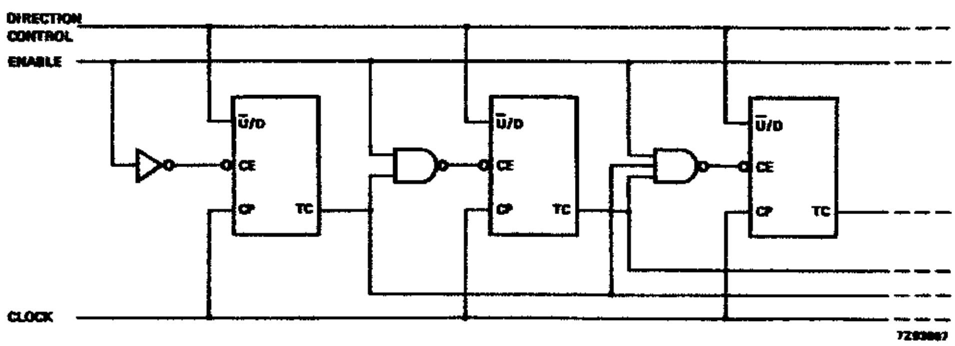


Fig.7 Synchronous n-stage counter with parallel gated carry/borrow.

Sequence
Load (present) to BCD seven;
count up to eight, nine, zero, one and two;
inhibit;
count down to one, zero, nine, eight and seven.

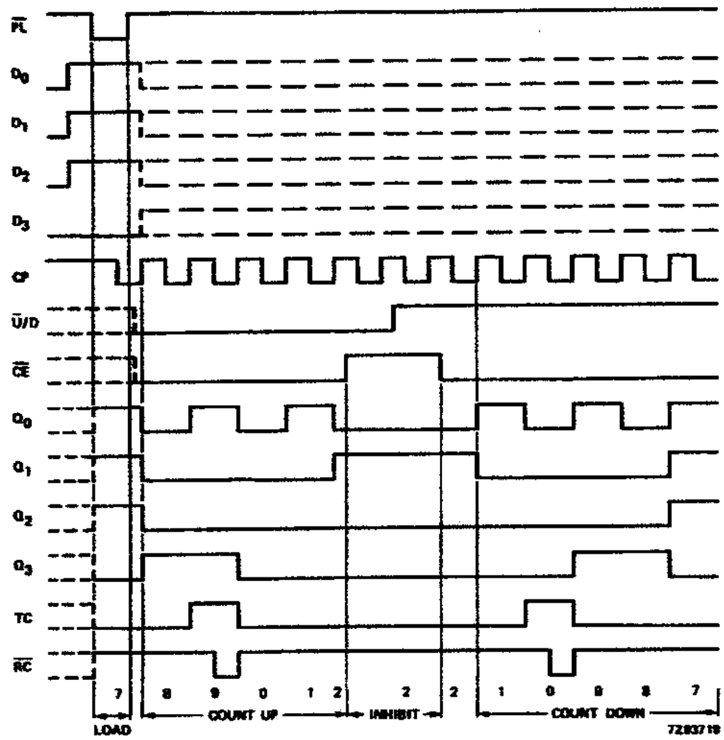


Fig.8 Typical load, count and inhibit sequence.

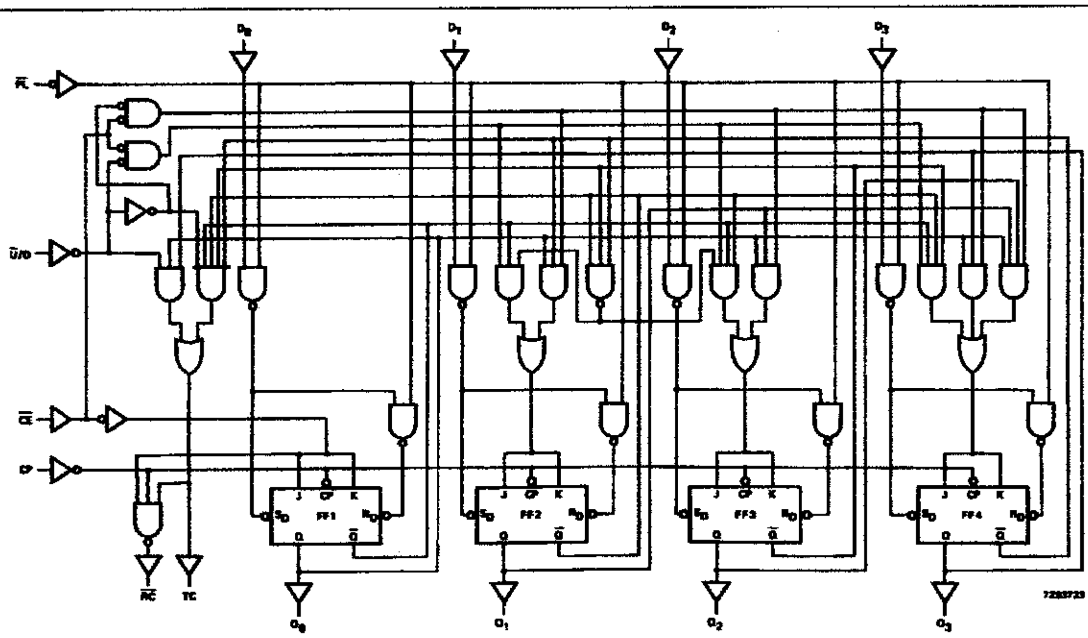


Fig.9 Logic diagram.

APPENDIX D

DATASHEET : 8-INPUT ANALOG MULTIPLEXER

TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS122A

November 1997 - Revised April 1999

CD54HC4051, CD74HC4051, CD74HCT4051, CD74HC4052, CD74HCT4052, CD74HC4053, CD74HCT4053

High Speed CMOS Logic Analog Multiplexers/Demultiplexers

Features

- **Wide Analog Input Voltage Range . . . . ±5V Max**
- **Low "On" Resistance**
  - **70Ω Typical (V_{CC} - V_{EE} = 4.5V)**
  - **40Ω Typical (V_{CC} - V_{EE} = 9V)**
- **Low Crosstalk between Switches**
- **Fast Switching and Propagation Speeds**
- **"Break-Before-Make" Switching**
- **Wide Operating Temperature Range . . -55°C to 125°C**
- **CD54HC/CD74HC Types**
  - **Operation Control Voltage . . . . 2V to 6V**
  - **Switch Voltage . . . . 0V to 10V**
  - **High Noise Immunity . . . N_{IL} = 30%, N_{IH} = 30% of V_{CC}, V_{CC} = 5V**
- **CD54HCT/CD74HCT Types**
  - **Operation Control Voltage . . . . 4.5V to 5.5V**
  - **Switch Voltage . . . . 0V to 10V**
  - **Direct LSTTL Input Logic Compatibility . . . V_{IL} = 0.8V Max, V_{IH} = 2V Min**
  - **CMOS Input Compatibility. . . . . $I_I \leq 1\mu A$ at V_{OL}, V_{OH}**

Description

These devices are digitally controlled analog switches which utilize silicon gate CMOS technology to achieve operating speeds similar to LSTTL with the low power consumption of standard CMOS integrated circuits.

These analog multiplexers/demultiplexers control analog voltages that may vary across the voltage supply range (i.e. V_{CC} to V_{EE}). They are bidirectional switches thus allowing any analog input to be used as an output and visa-versa. The switches have low "on" resistance and low "off" leakages. In addition, all three devices have an enable control which, when high, disables all switches to their "off" state.

Ordering Information

PART NUMBER	TEMP. RANGE (°C)	PACKAGE	PKG. NO.
CD54HC4051F	-55 to 125	16 Ld CERDIP	F16.3
CD74HC4051E	-55 to 125	16 Ld PDIP	E16.3
CD74HC4052E	-55 to 125	16 Ld PDIP	E16.3
CD74HC4053E	-55 to 125	16 Ld PDIP	E16.3
CD74HCT4051E	-55 to 125	16 Ld PDIP	E16.3
CD74HCT4052E	-55 to 125	16 Ld PDIP	E16.3
CD74HCT4053E	-55 to 125	16 Ld PDIP	E16.3
CD74HC4051M	-55 to 125	16 Ld SOIC	M16.15
CD74HC4052M	-55 to 125	16 Ld SOIC	M16.15
CD74HC4053M	-55 to 125	16 Ld SOIC	M16.15
CD74HCT4051M	-55 to 125	16 Ld SOIC	M16.15
CD74HCT4052M	-55 to 125	16 Ld SOIC	M16.15
CD74HCT4053M	-55 to 125	16 Ld SOIC	M16.15
CD74HCT4053PW	-55 to 125	16 Ld TSSOP	
CD74HCT4052SM	-55 to 125	16 Ld SSOP	M16.15A

NOTES:

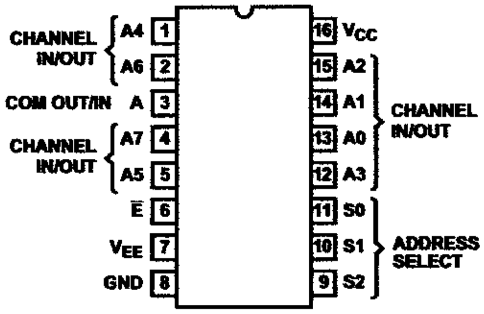
1. When ordering, use the entire part number. Add the suffix 96 to obtain the variant in the tape and reel. For the TSSOP package only, add the suffix R to obtain the variant in the tape and reel.
2. Wafer or die is available which meets all electrical specifications. Please contact your local sales office or Harris customer service for ordering information.

CAUTION: These devices are sensitive to electrostatic discharge. Users should follow proper IC Handling Procedures.

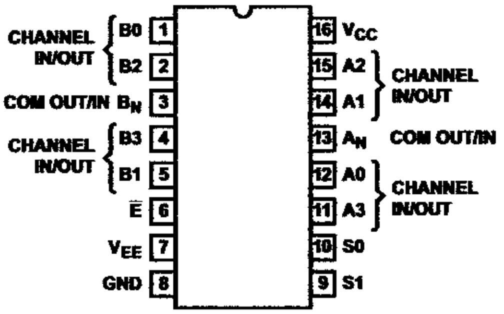
File Number **1676.1**

Pinouts

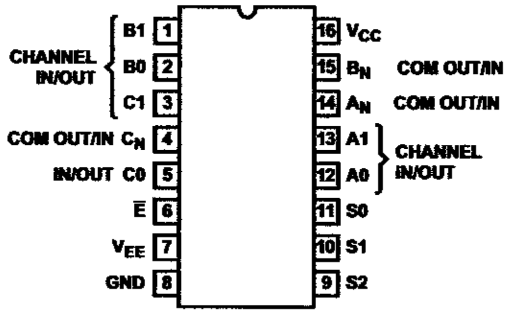
CD54HC4051
CD74HC4051, CD74HCT4051
(CERDIP, PDIP, SOIC)
TOP VIEW



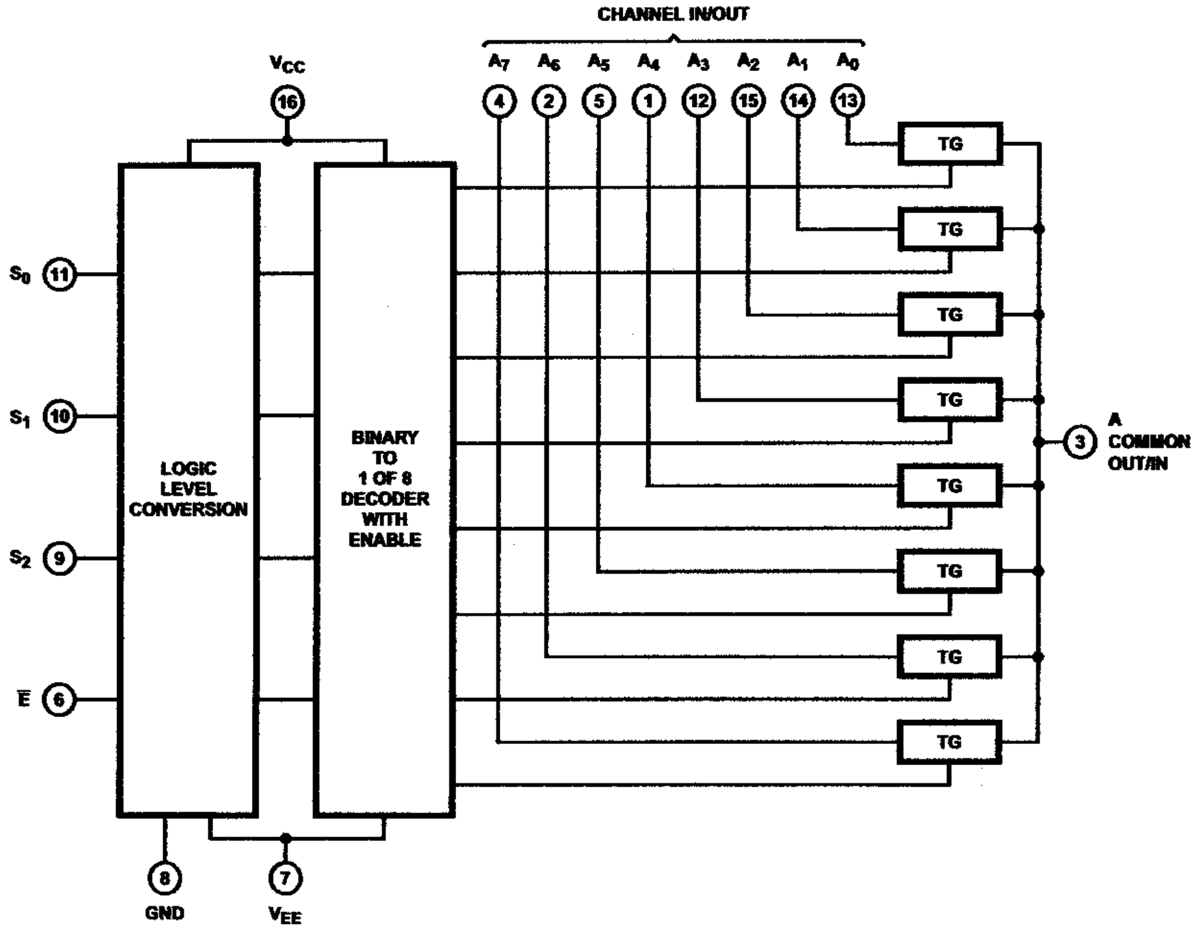
CD74HC4052, CD74HCT4052
(PDIP, SOIC)
TOP VIEW



CD74HC4053, CD74HCT4053
(PDIP, SOIC, TSSOP)
TOP VIEW



Functional Diagram of HC/HCT4051



TRUTH TABLE
CD54/74HC/HCT4051

INPUT STATES				"ON" CHANNELS
ENABLE	S_2	S_1	S_0	
L	L	L	L	A0
L	L	L	H	A1
L	L	H	L	A2
L	L	H	H	A3
L	H	L	L	A4
L	H	L	H	A5
L	H	H	L	A6
L	H	H	H	A7
H	X	X	X	None

X = Don't care