NOTRE DAME UNIVERSITY- Louaize

Faculty of Engineering

ECCE Department

EEN 312

Electronic Circuits Laboratory

Final Project

Road Gate with Special Car Access

Prepared by:

Anis Zebiane (20208081)

Firas Dimashki (20208022)

Presented to:

Ms. Nadine Zeineddine

Date:

15-May-2023

Table of Contents

List of Figures

List of Tables

I. Abstract

The objective of this project is to design and implement a smart road gate and a car which has special access to it. The road gate should be able to detect entering cars from both directions and open only during the day. At night the gate would not open for any cars except for our custom designed car. This would seem like a simple application had we used microcontrollers, but since this is a project for the electronics laboratory, no microcontroller was used, only pure electronics and some IC chips. In the end, the project fulfilled its purpose and was successful.

II. Introduction:

a. Design Objectives:

The objective of this experiment is to:

- Design a car that can be driven using a joystick.
- Design a road gate that opens and closes responding to the presence of cars.
- Dedicate the same road gate to open and close for special cars during the night.
- Implement the 2 designs using hardware components to test if they work accordingly together.

b. Theory and Analysis:

1. Diode:

The diode is a semiconductor device that functions as a unidirectional current switch. It permits current to move freely in one direction while severely limiting its flow in the opposite direction. The diode's polarity is determined by its anode (positive lead) and cathode (negative lead). In general, diodes only allow current to pass through when a positive voltage is applied to the anode. The diode has a wide range of uses in electronic circuits. The forward voltage drop, which should be around 0.7 volts, the reverse region, and the reverse breakdown voltage are three crucial properties of a diode.

Figure 1: General Purpose Diode and Diode Symbol

The current-voltage relationship of a diode is highly nonlinear. When a diode is forward biased, meaning that its anode is at a higher voltage potential than its cathode, it allows a significant amount of current to flow through it. In this state, the diode acts like a closed switch, and its resistance is very low, typically in the range of a few ohms or less.

However, when the diode is reverse biased, meaning that its cathode is at a higher voltage potential than its anode, it severely limits the current flow through it. In this state, the diode acts like an open switch, and its resistance is very high, typically in the range of megaohms or more.

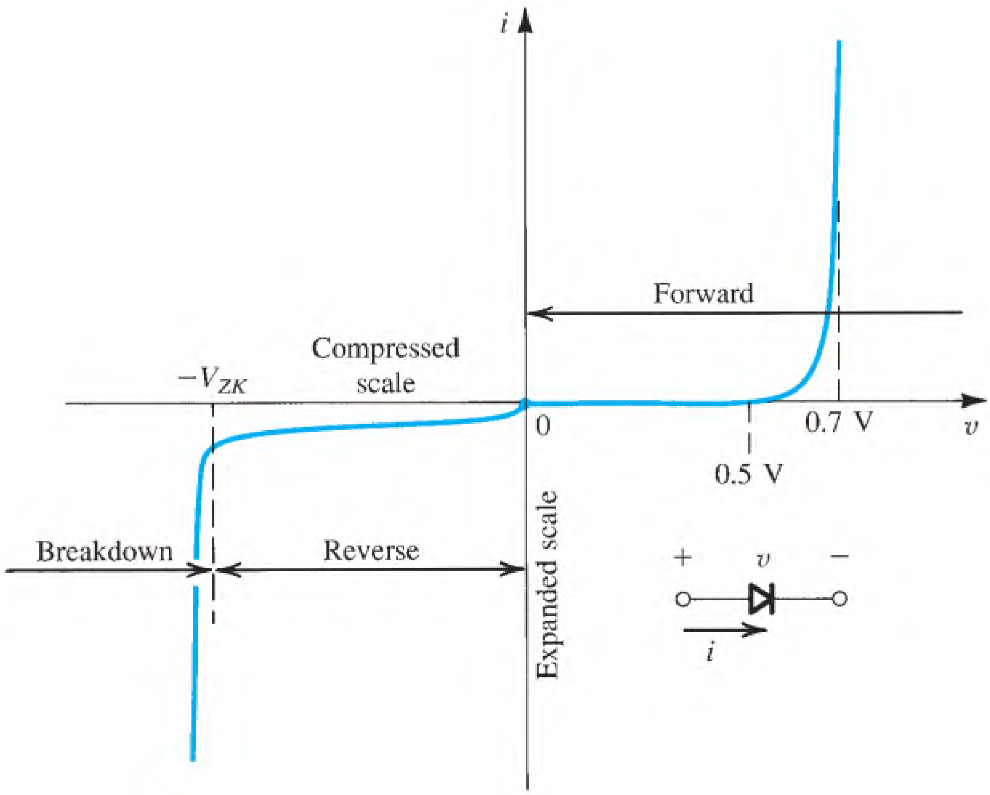


Figure 2: Current-Voltage Relationship of the Diode

The amount of current that flows through a diode in the forward direction depends on the voltage applied across it. The relationship between current and voltage is exponential, meaning that a small change in voltage can cause a large change in current. The relationship is often described by an equation called the Shockley diode equation, which takes into account various physical factors such as the diode's doping level, temperature, and other factors:

$$I = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$$

For a general-purpose diode, the breakdown voltage V_{ZK} is very large which means that the diode would not reach the breakdown region in most applications. However, for Zener diodes, this parameter is relatively small which is useful for some applications mentioned below.

2. Infrared Transmitter and Receiver

The infrared transmitter and receiver diodes are electronic components that emit and detect infrared (IR) light, respectively. An IR transmitter diode emits IR light when a current is passed through it. These diodes are commonly used in remote controls for TVs, DVD players, and other electronic devices. The IR signal from the transmitter diode is picked up by an IR receiver diode and decoded by the receiving device.

An IR receiver diode detects IR radiation and converts it into an electrical signal that can be used by an electronic device. They are used in a variety of applications, including proximity sensors, temperature sensors, and data communication systems. IR receiver diodes are often paired with an IR transmitter diode in a remote-control system to receive signals and control devices. The following image shows the IR transmitter (white) and IR receiver (black).

Figure 3: IR Transmitter and Receiver

Both IR transmitter and receiver diodes operate in the near-infrared region of the electromagnetic spectrum, with wavelengths ranging from approximately $750\ nm$ to $1\ mm$. Overall, IR transmitter and receiver diodes are important components in many electronic devices and systems that use IR radiation for communication, sensing, and control.

3. Bipolar Junction Transistor:

A bipolar junction transistor (BJT) is a three-terminal semiconductor device used to amplify or switch electronic signals. The three regions of a BJT are the emitter, base, and collector, with the base being the region sandwiched between the emitter and collector. There are two types of bipolar junction transistors: NPN and PNP. The main difference between them is the doping of the three semiconductor regions. The following figure shows the BJT (with metal case) and the BJT symbols for NPN and PNP transistors:

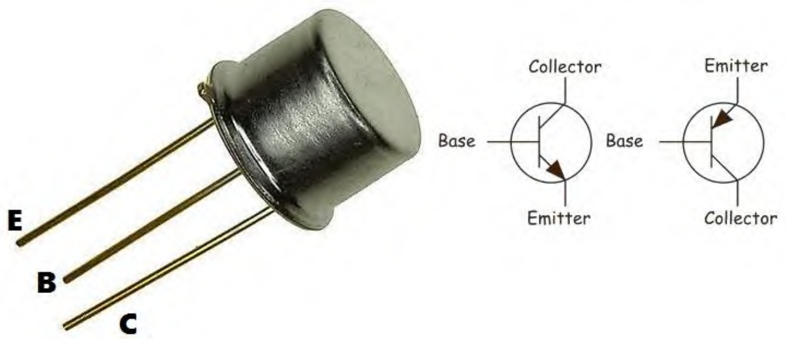


Figure 4: BJT with NPN and PNP Symbols.

In an NPN BJT, the emitter is heavily doped with electrons (n-type), while the base is lightly doped with holes (p-type), and the collector is moderately doped with electrons (n-type). The majority carriers in the NPN BJT are electrons, and the minority carriers are holes. When the base-emitter junction is forward-biased, electrons from the emitter flow into the base, where they combine with the holes, resulting in a current flow from the emitter to the collector.

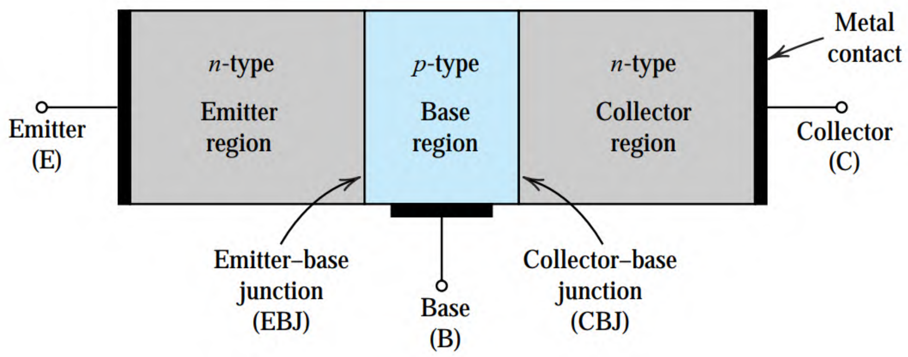


Figure 5: NPN Transistor Doping

In a PNP BJT, the emitter is heavily doped with holes (p-type), while the base is lightly doped with electrons (n-type), and the collector is moderately doped with holes (p-type). The majority carriers in the PNP BJT are holes, and the minority carriers are electrons. When the base-emitter junction is forward-biased, holes from the emitter flow into the base, where they combine with the electrons, resulting in a current flow from the emitter to the collector.

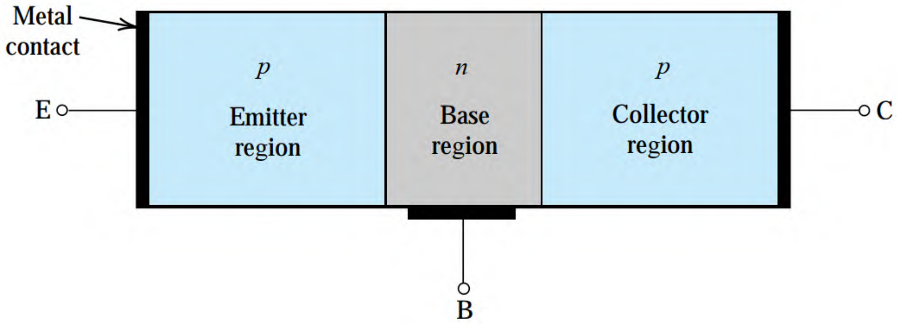


Figure 6: PNP Transistor Doping

The operation of NPN and PNP BJTs is very similar, but the current flows in opposite directions. In an NPN BJT, the current flows from the emitter to the collector, while in a PNP BJT, the current flows from the collector to the emitter. The base current controls the amount of current that flows from the emitter to the collector in both types of BJTs.

The BJT can operate on 3 different modes. The operating modes of a BJT are determined by the biasing conditions of its terminals and can be classified into three modes: the forward-active mode (or simply active mode), the cutoff mode, and the saturation mode.

The forward-active mode occurs when the base-emitter junction is forward-biased, and the base-collector junction is reverse-biased. In this mode, the BJT operates as an amplifier, with the emitter current being proportional to the base current. The collector current is controlled by the base current, and the gain of the BJT is defined as the ratio of the collector current to the base current. In the forward-active mode, the collector-emitter voltage is high enough to allow the BJT to operate in its linear region, which means that small changes in the base current result in corresponding changes in the collector current.

The saturation mode occurs when the base-emitter junction is forward-biased, and the base-collector junction is also forward-biased. In this mode, the BJT operates as a switch, and the collector current is at its maximum value. The saturation mode is useful for digital circuits and switching applications, where the BJT acts like a closed switch, allowing a current to flow from the collector to the emitter.

The graph below shows where the saturation and active modes are occurring according to the collector-base voltage (assuming that the base-emitter junction is forward biased where $V_{BE} \cong 0.7\ V$):

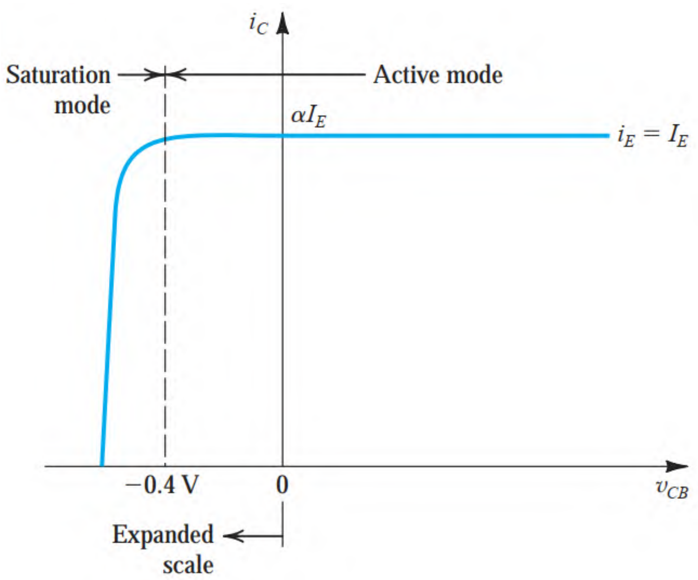


Figure 7: Saturation and Active Modes for NPN Transistors.

The cutoff mode occurs when the base-emitter junction is reverse-biased, and the base-collector junction is reverse-biased. In this mode, the BJT is turned off, and no current flows through the device. The BJT behaves like an open switch, and the collector-emitter voltage can be either high or low.

In summary, the operating modes of a BJT are determined by the biasing conditions of its terminals, with the forward-active mode being used for amplification, the cutoff mode for turning off the device, and the saturation mode for switching applications. Understanding the different operating modes of a BJT is essential for designing and analyzing electronic circuits that use these devices.

4. LM339 Comparator:

A comparator is a device that compares two input voltages and produces an output that indicates which one is greater. The comparator has two input terminals, one for each of the input voltages, and a single output terminal.

The output of the comparator is typically a digital signal, which is either high or low depending on the relative magnitudes of the input voltages. If the voltage at the inverting input is higher than the voltage at the non-inverting input, the output will be low. If the voltage at the non-inverting input is higher than the voltage at the inverting input, the output will be high.

Comparators are commonly used in electronic circuits for tasks such as level detection, window detection, and waveform shaping. They are also used in feedback loops to control the operation of amplifiers, regulators, and other circuits. Some comparators are specifically designed to operate at very high speeds, making them useful in applications such as telecommunications and high-speed signal processing.

The comparator used in this experiment is the LM339 quad comparator whose pinout is shown in the following figure.

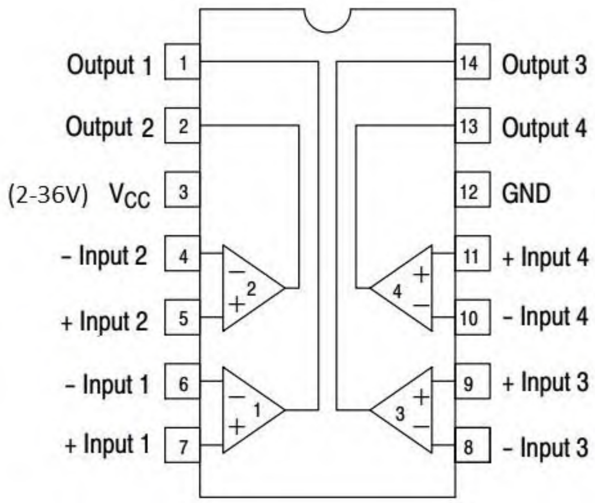


Figure 8: LM339 Quad Comparator

5. Relay:

Relays are electrical switches that are used to control the flow of current in a circuit. They work by using an electromagnetic coil to activate a set of contacts that open or close in response to changes in the coil's magnetic field. Relays are commonly used in a wide range of electronic and electrical systems to switch high voltage or high current loads.

Relays can be classified into different types based on their switching mechanism, such as electromagnetic relays, solid-state relays, reed relays, and hybrid relays. Electromagnetic relays are the most common type and consist of an electromagnet that is used to open or close the switch contacts. Solid-state relays, on the other hand, use semiconductor devices such as transistors and thyristors to perform switching, and are often used in high-speed switching applications.

Relays are often used in applications such as motor control, lighting control, HVAC (heating, ventilation, and air conditioning) control, and in industrial automation systems. They are also commonly used in automotive applications, such as in the control of lighting, power windows, and door locks. Relays offer several advantages over other types of switches, including their ability to switch high current and high voltage loads, their reliability, and their ease of use.

The relay used in this experiment is the Songle Relay SRD-12VDC-SL-C which is shown in the following figure.

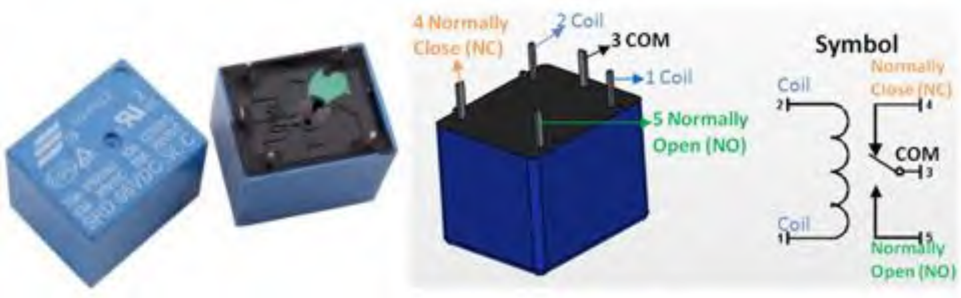


Figure 9:SRD-12VDC-SL-C Relay

6. 555 Timer:

The 555 timer IC is an integral part of electronics projects. Be it a simple project involving a single 8-bit microcontroller and some peripherals or a complex one involving system on chips (SoCs), a 555 timer is involved to provide time delays, as an oscillator, or as a flip-flop element among other applications.

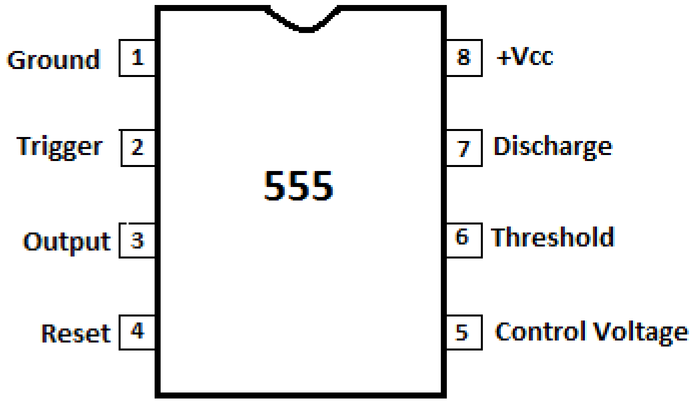


Figure 10: 555 Timer Pin Diagram

Depending on the manufacturer, the standard 555 timer package includes 25 transistors, 2 diodes, and 15 resistors on a silicon chip installed in an 8-pin mini dual-in-line package (DIP-8). Variants consist of combining multiple chips on one board. However, 555 is still the most popular.

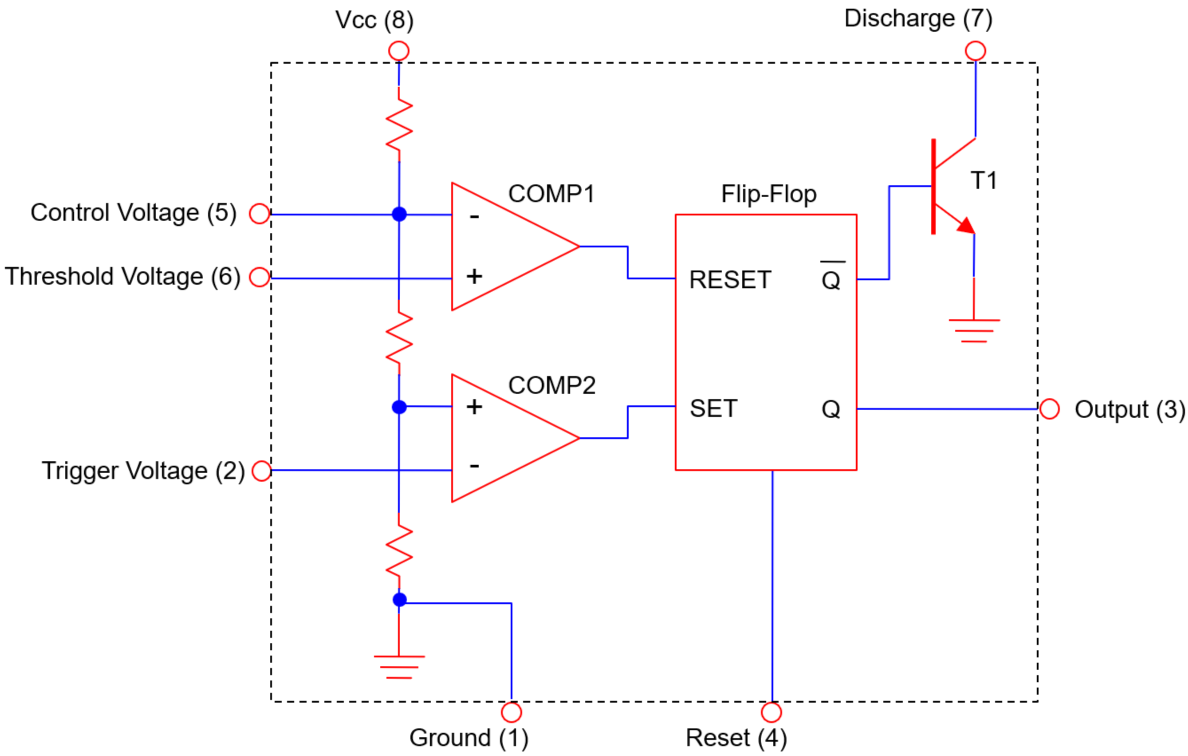


Figure 11: 555 Timer IC Internal Circuit.

The 555 timer operates in 3 different modes: Astable, Monostable and Bi-stable modes. The Astable mode means that there will be no stable level of output. So, the output will be swinging between high and low. This characteristic of unstable output is used as a clock or square wave output for many applications. The Monostable mode means that the configuration consists of one stable and one unstable state. The stable state can be chosen as either high or low by the user. If the stable output is set at HIGH (1), the output of the timer is HIGH. At the application of an interrupt, the timer output turns LOW (0). Since the low state is unstable it goes to HIGH automatically after the interrupt passes. Similar is the case for a low stable monostable mode. Whereas in the Bi-stable mode, both the output states are stable. At each interrupt, the output changes from LOW to HIGH and vice versa, and stays there. For example, if the output is initially HIGH, it would become LOW once it receives an interrupt and stay LOW till the next interrupt changes the status, which is similar to the operation of a flip-flop.

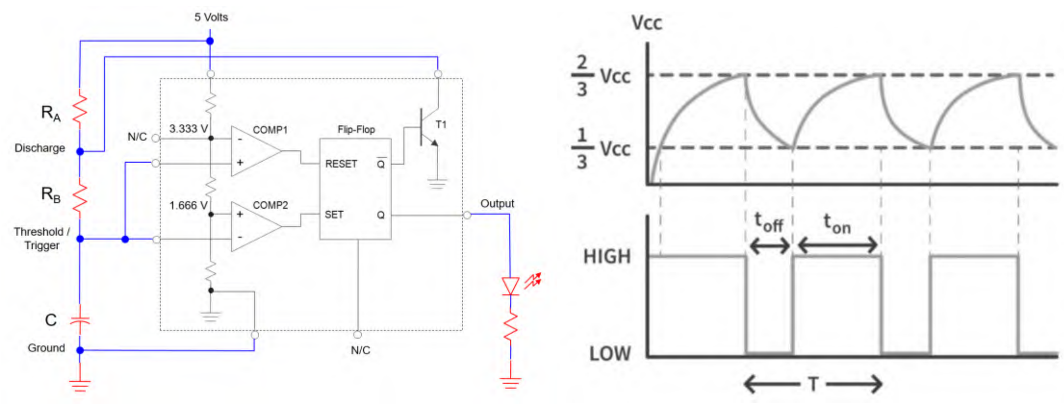


Figure 12: 555 Timer in the Astable Mode

7. Photo-Resistor:

Photoresistors, also known as light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. In the dark, their resistance is very high, sometimes up to 1 MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices.

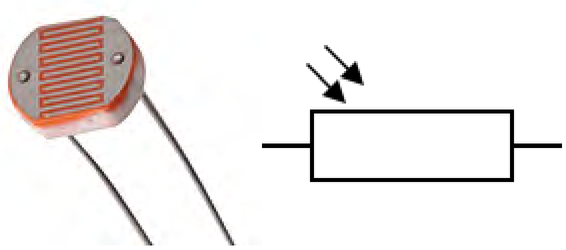


Figure 13: Photoresistor and its Symbol.

LDRs are used in many applications, but this light sensing function is often performed by other devices such as photodiodes and phototransistors. Some countries have banned LDRs made of lead or cadmium over environmental safety concerns.

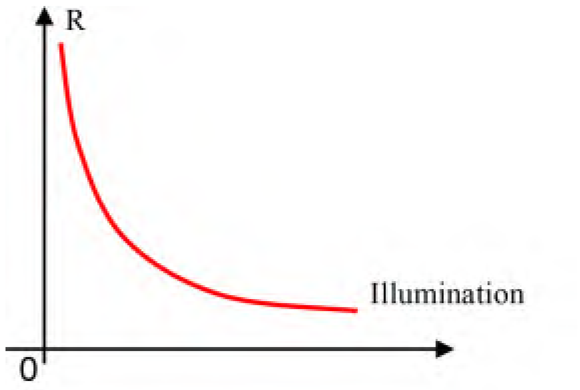


Figure 14: Variation of the Resistance of an LDR as a Function of Illumination.

8. Logic Gates:

The AND gate is a basic digital logic gate that implements logical conjunction (∧) from mathematical logic. A HIGH output (1) results only if all the inputs to the AND gate are HIGH (1). If none or not all inputs to the AND gate are HIGH, LOW output results. The function can be extended to any number of inputs. The IC 7408 is a Quad 2-Input AND gate, which means it contains 4 dual-input AND gates.

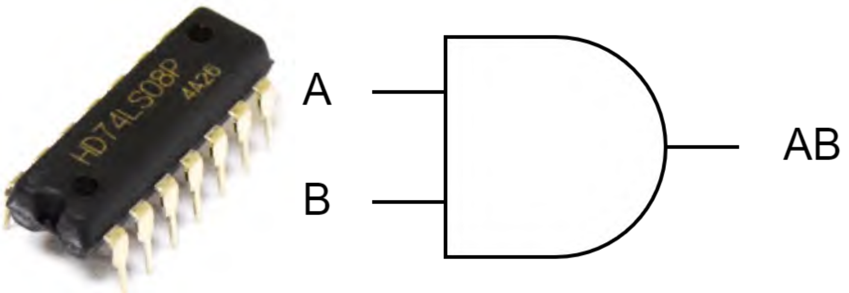


Figure 15: IC 7408 AND Gate and its Symbol

The OR gate is a dual-input logic gate which has a HIGH output if either or both inputs are HIGH. The NOT gate or inverter is another logic gate which has only one input. The inverter outputs HIGH only if the input is LOW. These two gates can be easily implemented using BJTs as shown in the following figure.

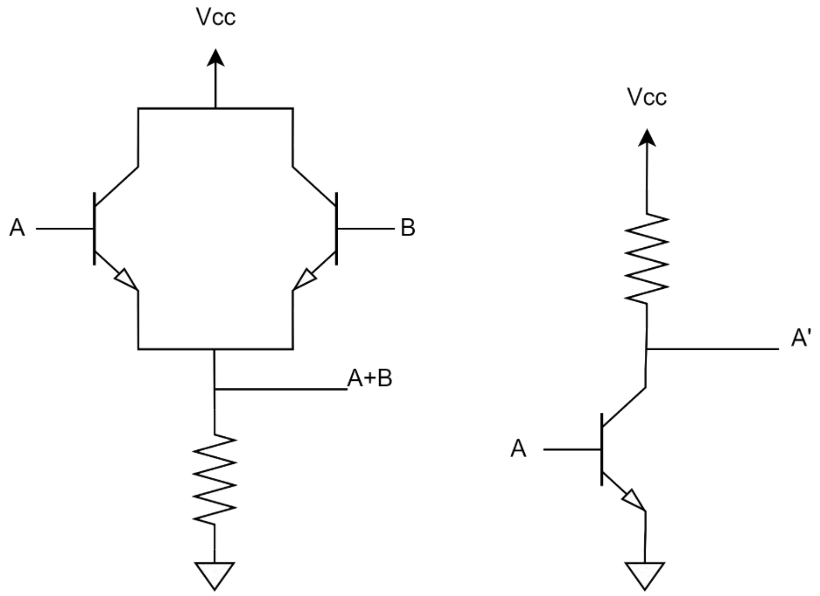


Figure 16: OR and NOT Gates Implemented Using BJTs

In both these gates, the BJTs act as open or closed switches between collector and emitter.

For the OR gate, when one or both inputs A and B is HIGH, at least one of the BJTs would act as a closed switch, so the output $A + B$ would be approximately equal to V_{cc} with a small collector-emitter voltage drop i.e., HIGH. If neither input is HIGH, the BJTs would act as open switches, so the output would be grounded i.e., LOW.

For the NOT gate, when the input A is HIGH, the BJT would act as a closed switch, so the output is LOW. If the input is LOW, the BJT would act as an open switch, so the output is HIGH.

9. IC 7473 JK Flip-Flop:

The 7473 is a type of JK flip-flop, which is a fundamental building block in digital electronics. It is a sequential logic device that can store one bit of information, represented by either logic 0 or logic 1 (LOW or HIGH). The 7473 JK flip-flop is designed to operate on a positive-edge triggered clock signal.

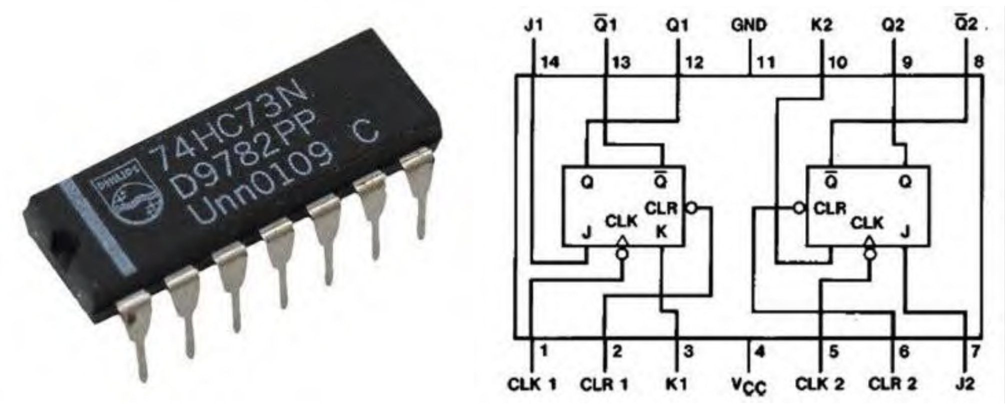


Figure 17: IC 7473 Dual JK Flip-Flop

Here are the key features and characteristics of the 7473 JK flip-flop:

- Inputs: The 7473 has two inputs, J and K, which are used to control the flip-flop's behavior. These inputs determine the state of the flip-flop when the clock signal rises from low to high (positive edge). The J input stands for "set," and the K input stands for "reset."
- Clock: The flip-flop is triggered by a clock signal, which determines when the inputs are sampled and the output is updated. The clock signal should be applied to the CLK (clock) input of the 7473. The flip-flop responds to the clock signal only when it transitions from low to high (positive edge).
- Output: The 7473 has two outputs, labeled Q and Q̅ (Q-bar). The Q output represents the current state of the flip-flop, while the Q̅ output represents the complement of the Q output.
- Operation: The behavior of the 7473 is determined by the combination of inputs J and K. The following rules apply:
  a. If both J and K are set to logic 0, the flip-flop remains in its current state (no change).
  b. If J is set to logic 1 and K is set to logic 0, the flip-flop is set (Q = 1).
  c. If J is set to logic 0 and K is set to logic 1, the flip-flop is reset (Q = 0).
  d. If both J and K are set to logic 1, the flip-flop toggles its state. If the current state is 0, it becomes 1, and if the current state is 1, it becomes 0.

- Asynchronous Inputs: The 7473 includes asynchronous inputs labeled PRESET (PR) and CLEAR (CLR). These inputs can override the behavior of J and K inputs, allowing for direct setting or resetting of the flip-flop's state regardless of the clock input.
- Power Supply: The 7473 operates with a typical power supply voltage of 5 volts (VCC).

It's worth noting that the 7473 JK flip-flop is a specific variant of the JK flip-flop family, and there are other types and variations available with different features and specifications. The 7473 is typically found as an integrated circuit (IC) package, allowing for easy implementation in digital circuits and systems.

10.L298N Motor-Driver:

The L298N motor driver is a popular integrated circuit that is used to control DC motors and stepper motors. It is a dual H-bridge driver, which means it can control two DC motors or one stepper motor. The L298N can handle a wide range of input voltages, up to 46V, and can supply up to 2A per channel. It also has built-in protection features such as thermal shutdown and overcurrent protection.

The L298N is commonly used in robotics projects, CNC machines, and other applications that require precise motor control. To use the L298N, it is typically connected to a microcontroller such as an Arduino, but in this project no microcontroller is used, so the driver is controlled using digital logic.

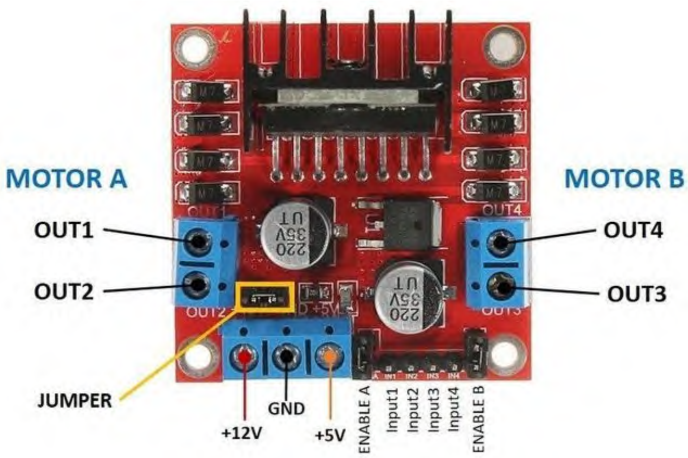


Figure 18: L298N Motor Driver Pinout

The operation of the L298N motor driver is summarized in the following table for Motor A, which also applies to Motor B.

Table 1: L298N Operation

ENA	IN1	IN2	Rotation
LOW	~	~	none
HIGH	LOW	LOW	none
HIGH	LOW	HIGH	clockwise
HIGH	HIGH	LOW	counterclockwise
HIGH	HIGH	HIGH	none

11.Joystick:

The joystick module is a commonly used input device in electronics projects. It consists of a joystick mechanism that can be moved in different directions, along with a potentiometer that detects the position of the joystick. The module usually has multiple pins for connecting to a microcontroller or other electronic circuit.

The joystick module provides analog output signals that correspond to the position of the joystick. These signals can be used to determine the direction and magnitude of movement in both the X and Y axes. The potentiometer's resistance changes as the joystick is moved, allowing the microcontroller to read the analog voltage and interpret the joystick's position.

Typically, the joystick module has a power supply pin, a ground pin, two analog output pins, and a pin for the built-in push button. The push button is open circuit when it is not pressed and grounded when it is pressed.

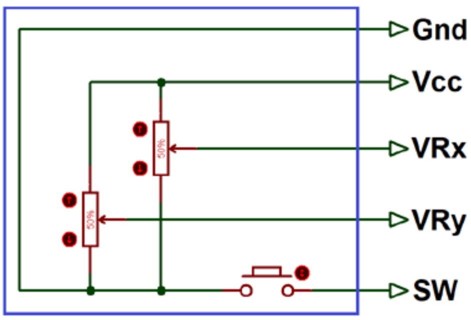


Figure 19: Joystick Module

12.Pulse Width Modulation (PWM):

Pulse Width Modulation (PWM) is a technique used to control the average voltage or current supplied to a load by rapidly switching a signal on and off. It is commonly used in electronic systems to control the speed of motors, regulate the brightness of LEDs, and perform various other tasks that require precise control over power delivery.

In PWM, a periodic signal, often referred to as the carrier signal or the PWM signal, is generated. The carrier signal usually has a fixed frequency and a varying duty cycle. The duty cycle represents the proportion of time the signal is ON (high) compared to the total period of the signal. By adjusting the duty cycle, the average power delivered to the load can be controlled.

For example, consider the case of controlling the brightness of an LED using PWM. If the LED is connected to a constant DC voltage, its brightness would be fixed. However, by applying PWM to the LED, the LED is rapidly switched on and off at a frequency that is typically higher than what the human eye can perceive. By varying the duty cycle, we can effectively control the perceived brightness. A higher duty cycle (longer ON time) will result in a brighter LED, while a lower duty cycle (shorter ON time) will result in a dimmer LED.

PWM signals can be generated using microcontrollers, specialized PWM modules, or dedicated PWM generator chips. The frequency of the PWM signal is usually fixed, but the duty cycle can be adjusted in software or hardware based on the desired control parameters.

PWM offers several advantages, such as efficient power usage since power is delivered in pulses rather than being continuously applied. It also provides precise control over the average voltage or current, allowing for smooth and accurate control of devices. PWM is widely used in applications like motor speed control, audio amplifiers, temperature regulation, and many other areas where precise control of power delivery is required.

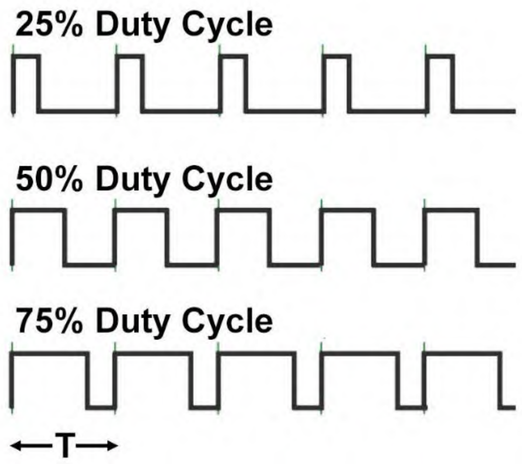


Figure 20: Pulse Width Modulation

13.Servomotor:

A servomotor, also known as a servo, is a type of motor that is designed for precise control of angular position. It is widely used in various applications that require accurate and controlled motion, such as robotics, remote-controlled vehicles, industrial automation, and hobby projects.

A servomotor consists of three main components: a DC motor, a position feedback sensor (usually a potentiometer or an encoder), and a control circuit. The control circuit receives input signals, typically in the form of pulses, and adjusts the motor's position based on these signals.

The control input for a servo is typically a PWM signal. The width of the pulse determines the desired position. A pulse with a shorter width indicates a desired position towards one extreme, while a longer pulse indicates a desired position towards the other extreme. The control circuit interprets the width of the pulse and adjusts the motor's position accordingly. This allows for precise and repeatable positioning within the servo's range of motion, which is usually around 180 degrees.

The position feedback sensor continuously monitors the actual position of the servo motor and provides feedback to the control circuit. This feedback allows the control circuit to compare the desired position with the actual position and make necessary adjustments to ensure accurate positioning. The feedback mechanism enables the servo to correct for external forces or disturbances that may affect its position.

Figure 21: Servomotor

The servo used in this project operates on 5 volts with a 50 hertz PWM signal whose duty cycle ranges from 2.5% to 12.5%. A duty cycle of 2.5% maps to an angle of 0°, 7.5% maps to 90°, and 12.5% maps to 180°.

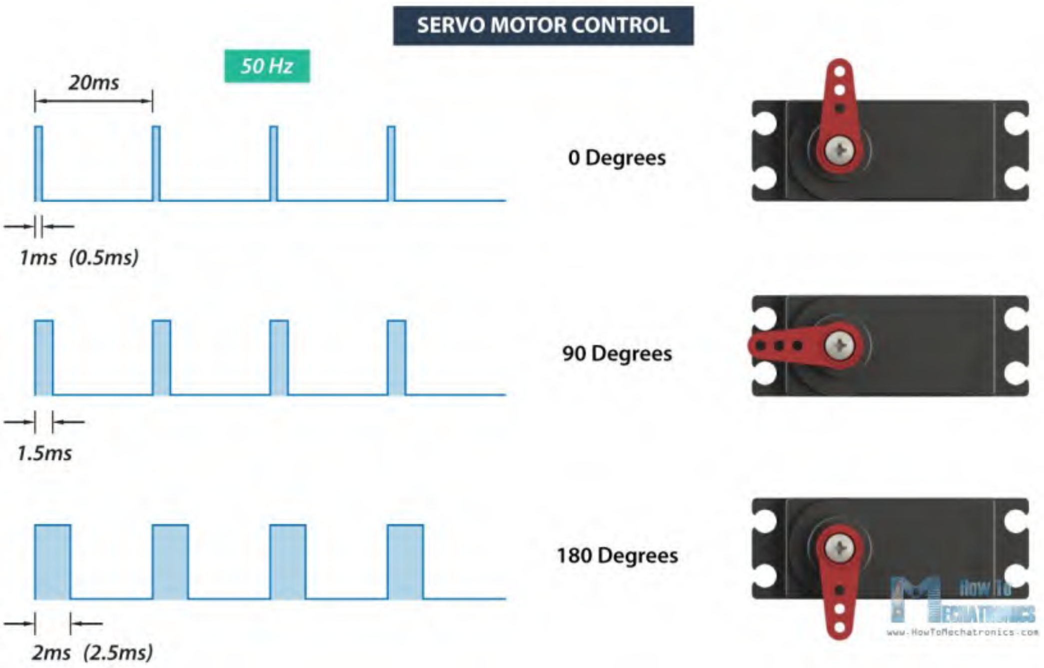


Figure 22: Servomotor Operation

III. Design Description:

a. List of Components:

Table 2: List of Components

Component	Quantity	Component	Quantity
470 kΩ Resistor	6	Photoresistor	1
1 kΩ Resistor	2	LM339 Comparator	2
1.5 kΩ Resistor	1	555 Timer	3
2 kΩ Resistor	1	IC 7473 JK Flip-Flop	1
3 kΩ Resistor	1	IC 7408 AND Gate	1
3.3 kΩ Resistor	1	L298N Motor Driver	1
4.7 kΩ Resistor	5	SRD-12VDC-SL-C Relay	1
5.1 kΩ Resistor	3	Joystick Module	1
10 kΩ Resistor	5	Passive Buzzer	1
100 kΩ Resistor	3	SG90 Servomotor	1
1 MΩ Resistor	1	DC Motor	2
10 kΩ Potentiometer	4	Push Button	1
100 kΩ Potentiometer	3	Switch	1
100 nF Capacitor	7	LM7805 5V Regulator	2
1 µF Capacitor	2	9V DC Adapter	1
10 µF Capacitor	1	4V Lithium Battery	2
D1N4007 Diode	5	Jumper Wires	~
2N2222A NPN BJT	4	Breadboards	~
IR Photodiode	4	Car Body + Wheels	1
IR LED	3		

b. Design Procedure:

Our final design of the project consists of 2 parts. The first part is the advanced road gate, and the second one is the special car that we designed.

The road gate circuit is connected as follows:

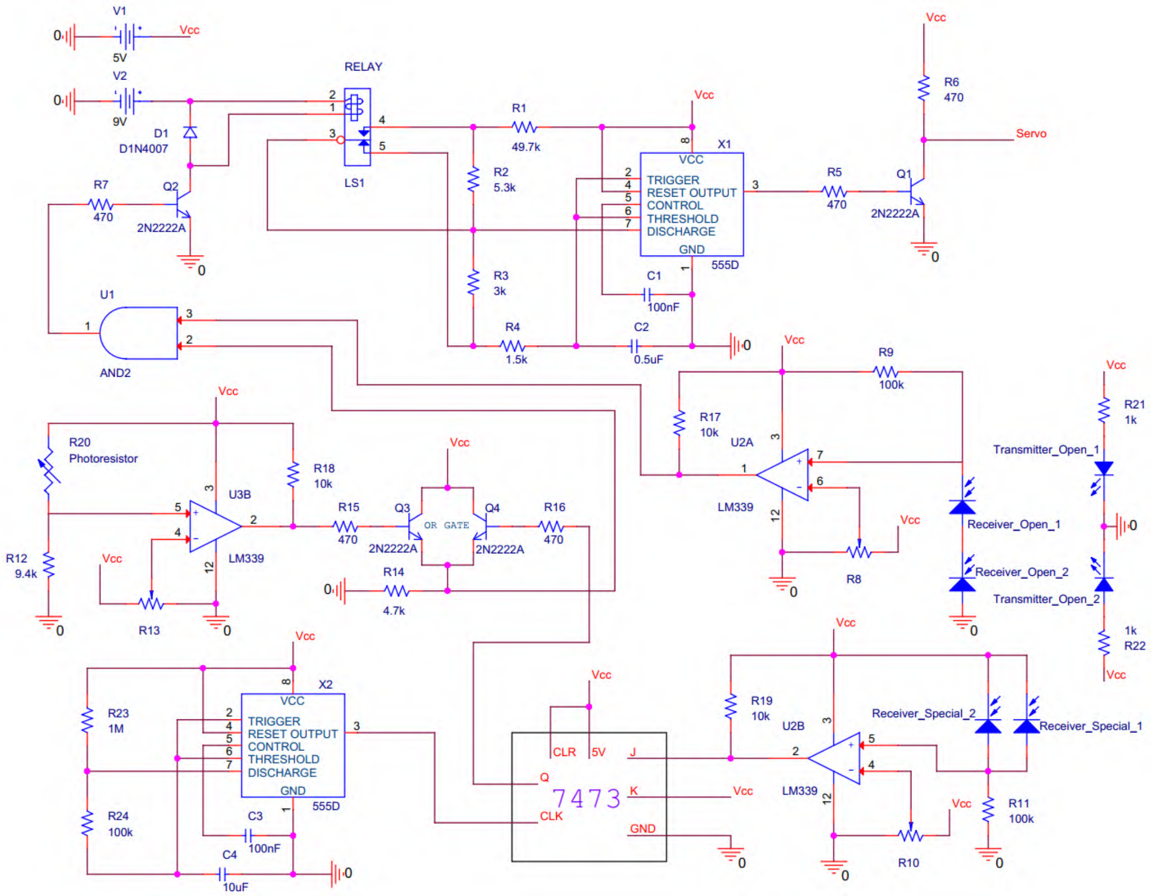


Figure 23: Gate Circuit Design

The special car circuit is connected as follows:

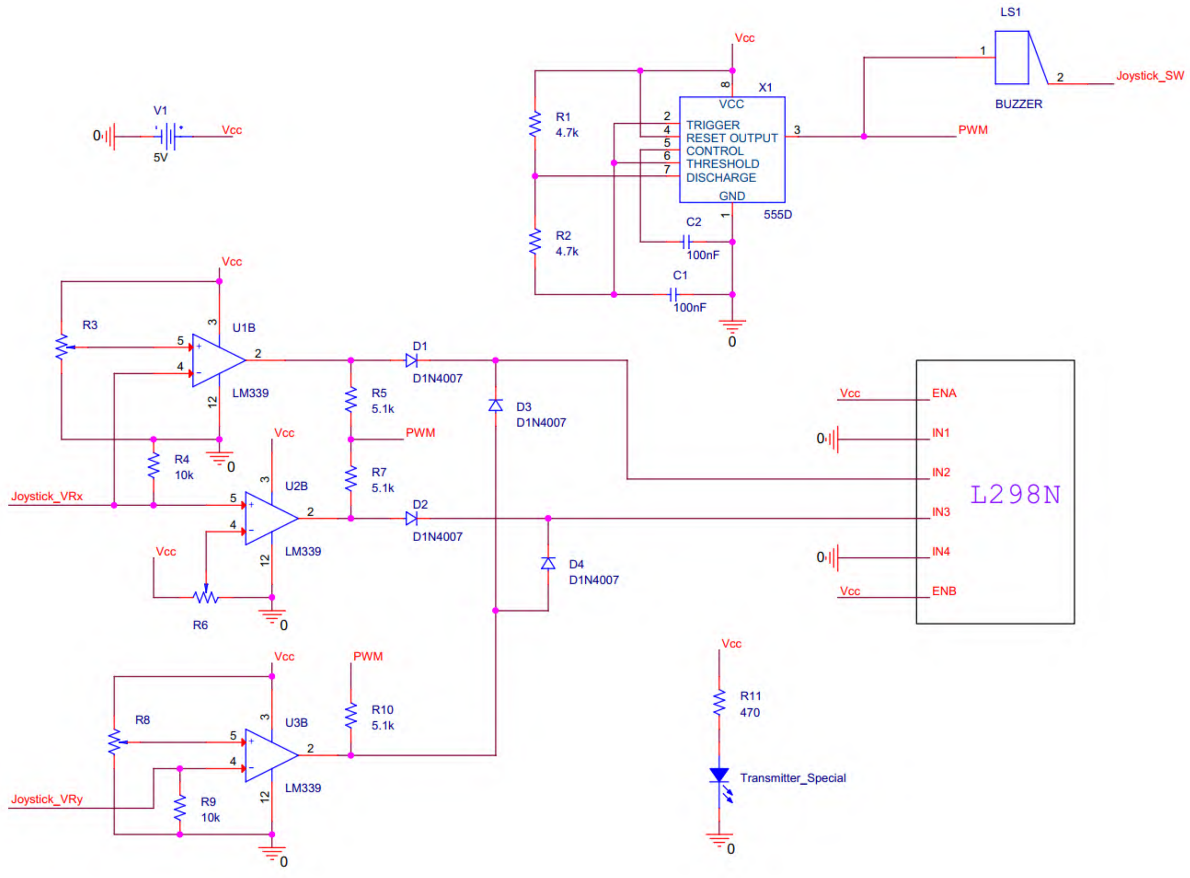


Figure 24: Special Car Circuit Design

IV. Results and Interpretation:

a. Circuit Analysis:

i. Road Gate Circuit:

Starting the analysis by designating the names of “Receiver Open” and “Receiver Special” for the receivers responsible for opening the gate of all type of cars, and for the receivers responsible for detecting the special car respectively.

The connection of the “Receiver Open” will allow the servomotor to open (turn 90°) only when one or both receivers is not receiving any signal from the transmitter, whereas the connection of the “Receiver Special” will allow the servomotor to open only when this receiver is receiving a signal (i.e., the special car is present). These two connections of receivers are connected to V_{cc}. Each output of the 2 receivers is sent to an input terminal of a comparator, where the latter would be outputting a high signal if the voltage at the + input (arriving from the transmitters) is lower than the voltage at the - input (arriving from a potentiometer that is regulated manually before testing or deployment, since many factors can affect the operation of the receivers such as the room light). The comparator would also be outputting a low signal if the voltage at the inverting input is higher than the voltage at the non-inverting input. On the other side, the operation of the photoresistor will depend on the light present in the surrounding area. With a high light input, its resistance will decrease, and it can be represented by a resistor with a very low resistance value. In this case, if we performed voltage division analysis, we would find that the voltage across R12 is very high hence a higher input voltage on the comparator's + input which will result in a HIGH output from the comparator. The reference voltage for the photoresistor in this case is also calibrated using a potentiometer.

The output of the comparator designated to the "Receiver Special" connection is sent to the J pin of the JK flip-flop to set the flip-flip output to HIGH. The clock that controls the change of the flip-flop is provided by a 555 timer that has a period of $T = 0.693(R_A + 2R_B)C = 8.316\ s$. The output of the flip-flop is connected to the BJT OR gate along with the output of the comparator connected to the photoresistor.

This output voltage is connected to one of the inputs of the AND gate, while the second input will be receiving signal from the output of the comparator designated to the "Receiver Open" connection. The following scenario will occur across the AND gate:
If "Receiver Open" is detecting an obstacle (i.e., a car) **AND** there is either light received by the photoresistor **OR** the special car is present at the gate (which means that "Receiver Special" is receiving a signal), the AND gate will give a HIGH output, and that will lead the BJT Q2 to act as a closed switch, and hence the relay is in the normally open (NO) configuration. However, if the previously stated condition is not satisfied, the AND gate will give a LOW output which will cause the relay to be in the normally closed (NC) configuration. The relay is connected such that the COM terminal is connected to the Discharge terminal of the 555 timer, NC to R4 and NO to R1. The concept of this connection is to change the resistances that are connected to the timer, thus changing the duty cycle of the output signal.

Since the high (ON) and low (OFF) periods of the timer can be calculated as:

$$T_{ON} = 0.693(R_A + R_B)C$$

$$T_{OFF} = 0.693R_BC$$

It is clear that for any component values, $T_{ON} = T_{HIGH} > T_{OFF} = T_{LOW}$ so $DC > 50\%$. But in our case, the exact opposite is required because the servomotor needs a 2.5% to 7.5% duty cycle PWM, which means we need $T_{HIGH} < T_{LOW}$. The best way to do this is to invert the output signal of the timer (i.e., HIGH input results in LOW output and vice versa). The inverter is designed using a BJT (Q1), such that when the output of the timer is HIGH, the BJT would act as a closed switch and hence the signal pin of the servomotor would be grounded (i.e., LOW). However, if the output of the timer is LOW, the BJT will act as an open switch and the servomotor signal pin would be connected to V_{cc} (i.e., HIGH).

The output of the timer will be classified into 2 cases:

Case 1: If the output of the AND gate is LOW, the relay will be in the normally closed configuration. In this case, R3 is short circuited, and hence the first and second resistances of the timer along with the frequency (f) and duty cycle (DC) would be as follows:

$$R_A = R_1 + R_2 = 55\ k\Omega$$

$$R_B = R_4 = 1.5\ k\Omega$$

$$f_2 = \frac{1}{0.693(R_A + 2R_B)C} = 49.655Hz$$

$$DC_2 = \frac{R_A + R_B}{R_A + 2R_B} \cdot 100 = 97.41\%$$

Case 2: If the output of the AND gate is HIGH, the relay will be in the normally open configuration. In this case, R2 is short circuited, and hence the first and second resistances of the timer along with the frequency (f) and duty cycle (DC) would be as follows:

$$R_A = R_1 = 49.7\ k\Omega$$

$$R_B = R_3 + R_4 = 3k + 1.5k = 4.5\ k\Omega$$

$$f_1 = \frac{1}{0.693(R_A + 2R_B)C} = 49.063Hz$$

$$DC_1 = \frac{R_A + R_B}{R_A + 2R_B} \cdot 100 = 92.33\%$$

After inverting the output of the timer, the new duty cycles would be the old ones subtracted from 100:

$$DC_{1_{NEW}} = 100 - DC_1 = 2.59\%$$

$$DC_{2_{NEW}} = 100 - DC_2 = 7.67\%$$

The new results are what is required for the servo to function as desired. In case 1 the PWM provided to the servo is a 2.59% $49.7Hz$ signal which would turn the servo to 0°. In case 2 the PWM provided to the servo is a 7.67% $49.1Hz$ signal which would turn the servo to 90°.

ii. Special Car Circuit:

The 555 timer on the car would provide a PWM with the following values:

$$T_{ON} = 0.693(R_1 + R_2)C = 0.6514\ ms$$

$$T_{OFF} = 0.693R_2C = 0.3257\ ms$$

$$f = \frac{1}{0.693(R_1 + 2R_2)C} = 1021.2766\ Hz$$

$$DC = \frac{R_1 + R_2}{R_1 + 2R_2} \cdot 100 = 66.67\%$$

This PWM is used for two reasons: it provides the AC signal to the buzzer (speaker) to produce sound, and it decreases the speed of the DC motors.

As seen in the circuit, the buzzer ground is connected to the “Joystick SW” pin of the joystick, that actually provides ground voltage level when the joystick is pressed, ensuring a closed circuit for the buzzer which will output a 1 kHz sound (emulating a car horn).

The joystick movement pins “Joystick VRx” and “Joystick VRy” are connected to comparators which would output HIGH as the joystick is moved towards the edges. For instance, when the joystick is moved forward, the joystick outputs a low voltage on “Joystick VRy” which would cause the – Input of the comparator to be less than the + Input calibrated using the potentiometer, so the comparator would output HIGH. Note that normally, moving the joystick forward would output a high voltage, but in this case, the joystick is fixed in the opposite direction for better physical design.

Similarly, horizontal movement of the joystick would result in increasing and decreasing the voltage accordingly and one of the comparators connected to the “Joystick VRx” pin would output HIGH.

In this context, HIGH corresponds to the output PWM of the timer while LOW corresponds to ground. The PWM is used to decrease the power supplied to the motor driver without compromising the supplied voltage, thus the DC motors would turn slower than if they were connected directly to the DC supply voltage V_{cc}.

Since we are dealing with multiple inputs into the pins of the motor driver, diodes are added to connect the different outputs of the comparators. Without the presence of these diodes, there might be two comparator outputs connected to each other which is not a good electronics practice and that might cause circuit or IC failure. The diodes in this case may be considered an OR gate because if either the horizontal, vertical, or both movements are detected by the joystick, there would be a HIGH output.

Concerning the L298N Motor Driver, the pins IN1 and IN4 are connected to the ground, ENA and ENB are connected the voltage source V_{cc}. Whereas IN2 and IN3 are connected to the outputs of the comparators, and these 2 behave accordingly, such that when the first is HIGH and the second pin is LOW, one of the motors would be turn and the car would turn to the opposite side of the wheel, when the inputs are reversed the other motor would turned, and when both pins IN2 and IN3 are HIGH both motors would turn and the car would move forward. All these cases are decided by the user’s input on the joystick.

Finally, the IR transmitter “Transmitter Special” is present to indicate the presence of our special car at the road gate. The “Receiver Special” in the road gate circuit receives the IR rays from this transmitter to allow the car to pass through even at night.

b. Experimental Results:

After testing the circuit, everything was recorded to operate as intended, so the project prototype is successful. During the day, when any car approaches the gate, the gate would open, wait while the car crosses, then close. During the night, when a regular car approaches the gate, the gate would not open. It would only open for the special car that we designed, but the car may have to wait around 8 seconds or less for the gate to open, and it has a little over 8 seconds to pass the gate or else the gate would close, and the car would have to wait another 8 seconds for it to open (this is because of the designed JK flip-flop operation). The car that we designed also worked as intended where the user can control it using the joystick to move forward, right, and left and press the joystick button to sound the horn. Note that before testing/using the prototype, all potentiometers connected as reference voltage providers to the comparator must be calibrated, especially for the road gate that is easily affected by the light in the room.

V. Conclusion:

As a conclusion, we were able to design a smart road gate and car using pure electronics and basic ICs. We utilized many electronics concepts to operate the various electrical components like the servomotor and DC motors. After testing the prototype, we can confidently say that our designs are successful. This prototype may be used in many places where an automatic road gate is needed, like our university’s entrance and exit. The special car can be depicted as a car for the people who direct, manage, and watch the university. Overall, this design can be useful for smart control of a road gate in many applications.

VI. Appendix:

- The actual details of how the actual circuit was built were left out of this report because they may be irrelevant. For example, some capacitors were used for stabilizing the voltage in the circuit. Some resistors and capacitors were grouped in series or parallel to obtain the desired impedances. One potentiometer is used as a regular resistor because the desired resistance is not a standard value. The push button is connected between one of the coil terminals of the relay and ground to manually open the gate. A switch is placed with the car circuit to turn the car on and off.
- The power supplied for the circuits is as follows. For the gate circuit, a 9V adapter is used which can provide the required 9V for the relay, and it is regulated to 5V using an LM7805 voltage regulator for the rest of the circuit. For this regulation we could have used a Zener diode, but IC regulators are more precise and deliver more power than Zener diodes. For the car circuit, two lithium batteries were used to provide the motor driver with power for the DC motors. Each battery supplies around 4V, and they are connected in series to obtain around 8V for the motors. The battery voltage is also regulated to 5V using the same regulator as before for the rest of the car circuit.
- Instead of using a passive buzzer for the car horn, a speaker can be used, but the buzzer takes up less space and weight than the speaker, and it does not emit a strong magnetic field like the speaker does, so a buzzer would be more convenient for this application.
- Initially, we intended to build a BJT AND gate instead of using the IC, but the designed gate did not work as expected, so we decided to use the 7408 IC instead.
- Initially, we intended to use two relays to control the DC motors instead of the L298N chip. This would have worked if we intended to drive the DC motors at full speed by providing them with a DC voltage. However, since we used PWMs to decrease the speed of the motors, the relays would not work because that would require an extremely fast switching speed, and that is not possible. As a result, we chose to use the L298N chip because it accepts PWM signals as input for controlling the motors.
- To be able to prevent the gate from closing after 8 seconds from opening and maintain some time for the car to cross (case at night and presence of special car), more logic circuits must be added including counters.

- The following photographs show our final design and packaging of the project:

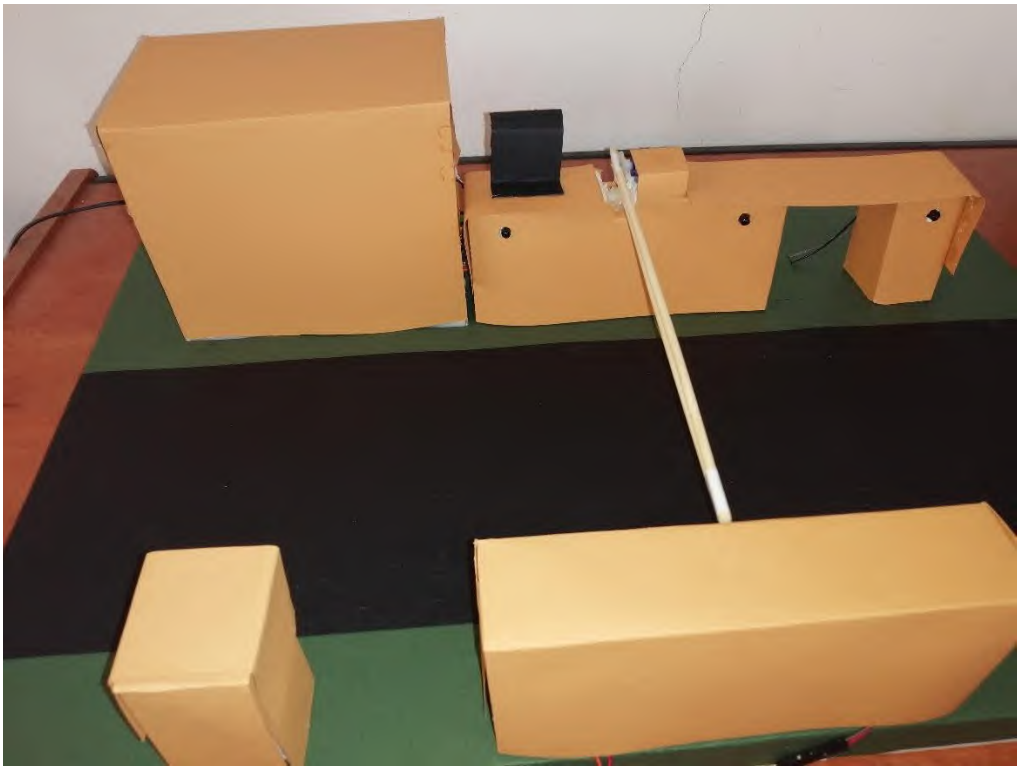


Figure 25: Project Photograph 1

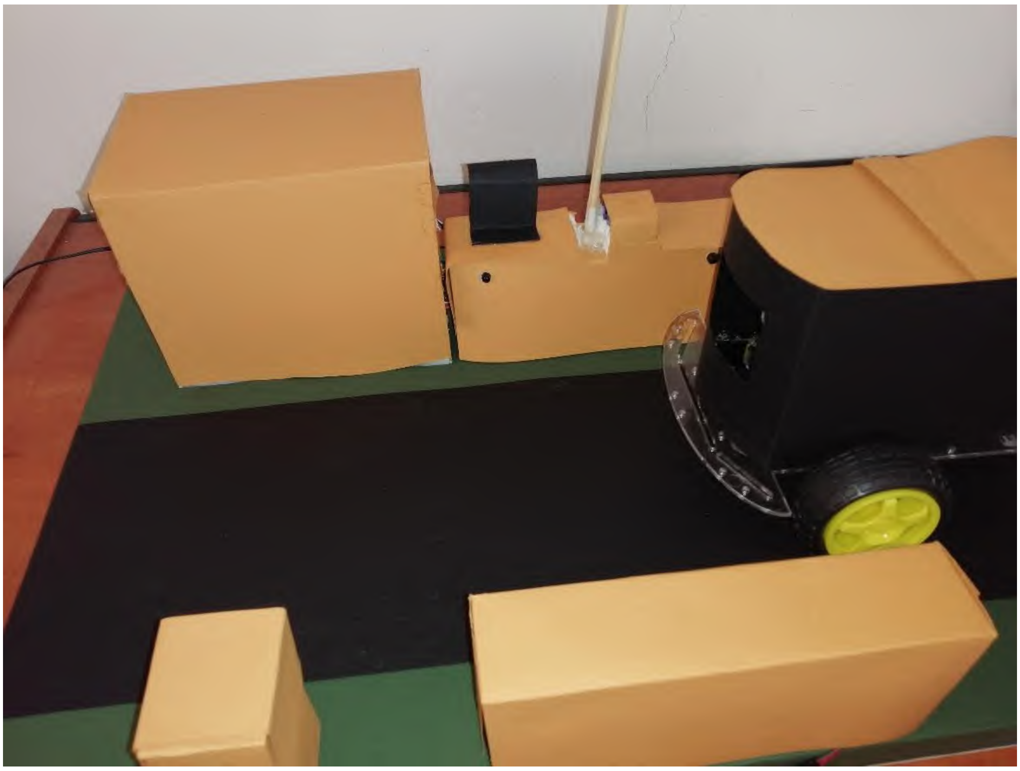


Figure 26: Project Photograph 2

- 1N4001-1N4007 diode series datasheet (note that using other models from this series should not affect the results of this experiment because they only differ in reverse voltage which is not reached in this project):

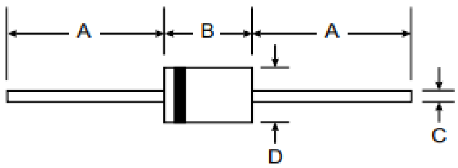
DIODES INCORPORATED

1N4001G/L - 1N4007G/L

1.0A GLASS PASSIVATED RECTIFIER

Features

- Glass Passivated Die Construction
- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Plastic Material - UL Flammability Classification 94V-0



Mechanical Data

- Case: Molded Plastic
- Terminals: Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Weight: DO-41 0.30 grams (approx)
  A-405 0.20 grams (approx)
- Mounting Position: Any
- Marking: Type Number

	DO-41 Plastic		A-405	
Dim	Min	Max	Min	Max
A	25.40	—	25.40	—
B	4.06	5.21	4.10	5.20
C	0.71	0.864	0.53	0.64
D	2.00	2.72	2.00	2.70
All Dimensions in mm				

"L" Suffix Designates A-405 Package
No Suffix Designates DO-41 Package

Maximum Ratings and Electrical Characteristics

@ $T_A = 25°C$ unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001 G/GL	1N4002 G/GL	1N4003 G/GL	1N4004 G/GL	1N4005 G/GL	1N4006 G/GL	1N4007 G/GL	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ $T_A = 75°C$	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load (JEDEC Method)	I_{FSM}	30							A
Forward Voltage @ $I_F = 1.0A$	V_{FM}	1.0							V
Peak Reverse Current @ $T_A = 25°C$ at Rated DC Blocking Voltage @ $T_A = 125°C$	I_{RM}	5.0 50							µA
Reverse Recovery Time (Note 3)	t_{rr}	2.0							µs
Typical Junction Capacitance (Note 2)	C_j	8.0							pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Operating and Storage Temperature Range	T_j, T_{STG}	-65 to +175							°C

Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
2. Measured at 1.0 MHz and applied reverse voltage of 4.0V DC.
3. Measured with $I_F = 0.5A$, $I_R = -1A$, $I_{rr} = 0.25A$.

Figure 27: 1N4007 Datasheet Screenshot 1

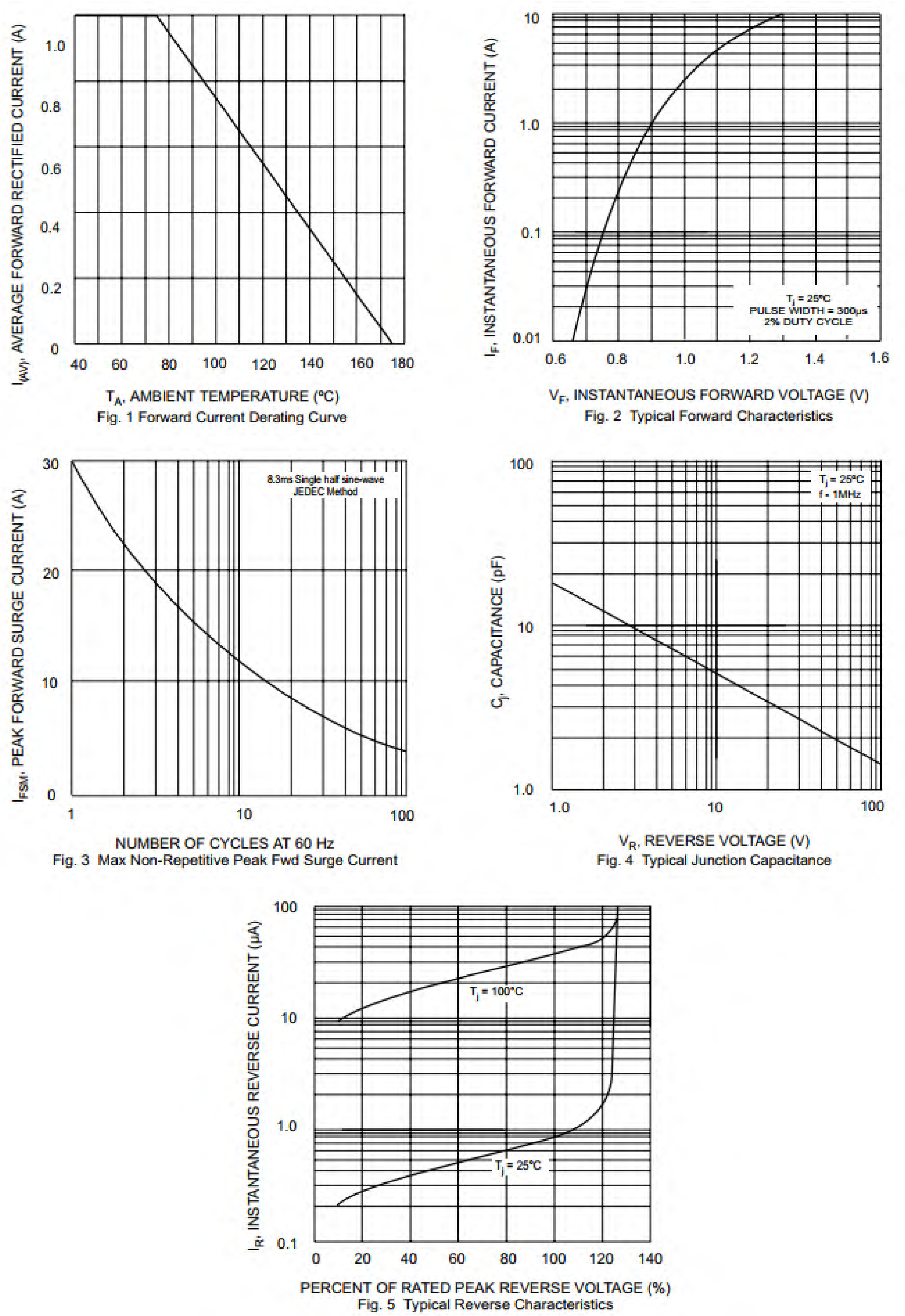


Figure 28: 1N4007 Datasheet Screenshot 2

- IR Transmitter datasheet:

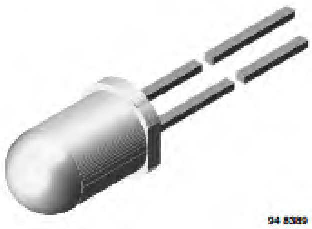
VISHAY.

www.vishay.com

TSAL6100

Vishay Semiconductors

High Power Infrared Emitting Diode, 940 nm, GaAlAs, MQW



94 8389

DESCRIPTION

TSAL6100 is an infrared, 940 nm emitting diode in GaAlAs multi quantum well (MQW) technology with high radiant power and high speed molded in a blue-gray plastic package.

FEATURES

- Package type: leaded
- Package form: T-1¾
- Dimensions (in mm): Ø 5
- Peak wavelength: λ_p = 940 nm
- High reliability
- High radiant power
- High radiant intensity
- Angle of half intensity: $\varphi = \pm 10°$
- Low forward voltage
- Suitable for high pulse current operation
- Good spectral matching with Si photodetectors
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT
HALOGEN FREE
GREEN (5-2008)

APPLICATIONS

- Infrared remote control units with high power reqirements
- Free air transmission systems
- Infrared source for optical counters and card readers
- IR source for smoke detectors

PRODUCT SUMMARY				
COMPONENT	I_e (mW/sr)	φ (deg)	λ_p (nm)	t_r (ns)
TSAL6100	170	± 10	940	15

Note
- Test conditions see table "Basic Characteristics"

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	REMARKS	PACKAGE FORM
TSAL6100	Bulk	MOQ: 4000 pcs, 4000 pcs/bulk	T-1¾

Note
- MOQ: minimum order quantity

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Peak forward current	$t_p/T = 0.5$, $t_p = 100$ µs	I_{FM}	200	mA
Surge forward current	$t_p = 100$ µs	I_{FSM}	1.5	A
Power dissipation		P_V	160	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	-40 to +85	°C
Storage temperature range		T_{stg}	-40 to +100	°C
Soldering temperature	t ≤ 5 s, 2 mm from case	T_{sd}	260	°C
Thermal resistance junction/ambient	J-STD-051, leads 7 mm soldered on PCB	R_{thJA}	230	K/W

Figure 29: TSAL6100 Datasheet Screenshot 1

VISHAY. www.vishay.com

TSAL6100

Vishay Semiconductors

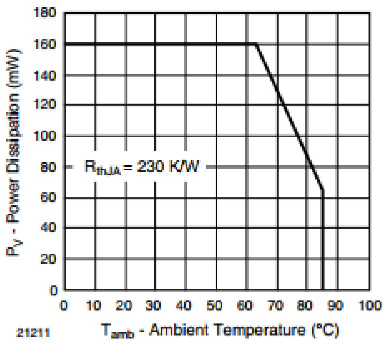


Fig. 1 - Power Dissipation Limit vs. Ambient Temperature

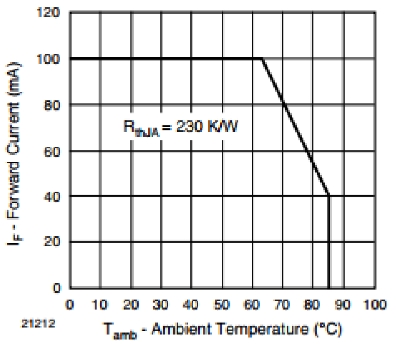


Fig. 2 - Forward Current Limit vs. Ambient Temperature

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Forward voltage	I_F = 100 mA, t_p = 20 ms	V_F		1.35	1.6	V
	I_F = 1 A, t_p = 100 μs	V_F		2.2	3	V
Temperature coefficient of V_F	I_F = 1 mA	TK_{VF}		-1.8		mV/K
Reverse current	V_R = 5 V	I_R			10	μA
Junction capacitance	V_R = 0 V, f = 1 MHz, E = 0	C_j		40		pF
Radiant intensity	I_F = 100 mA, t_p = 20 ms	I_e	80	170	400	mW/sr
	I_F = 1 A, t_p = 100 μs	I_e	650	1450		mW/sr
Radiant power	I_F = 100 mA, t_p = 20 ms	ϕ_e		40		mW
Temperature coefficient of ϕ_e	I_F = 20 mA	$TK\phi_e$		-0.6		%/K
Angle of half intensity		φ		± 10		deg
Peak wavelength	I_F = 100 mA	λ_p		940		nm
Spectral bandwidth	I_F = 100 mA	$\Delta\lambda$		30		nm
Temperature coefficient of λ_p	I_F = 100 mA	$TK\lambda_p$		0.2		nm/K
Rise time	I_F = 100 mA	t_r		15		ns
Fall time	I_F = 100 mA	t_f		15		ns

Figure 30: TSAL6100 Datasheet Screenshot 2

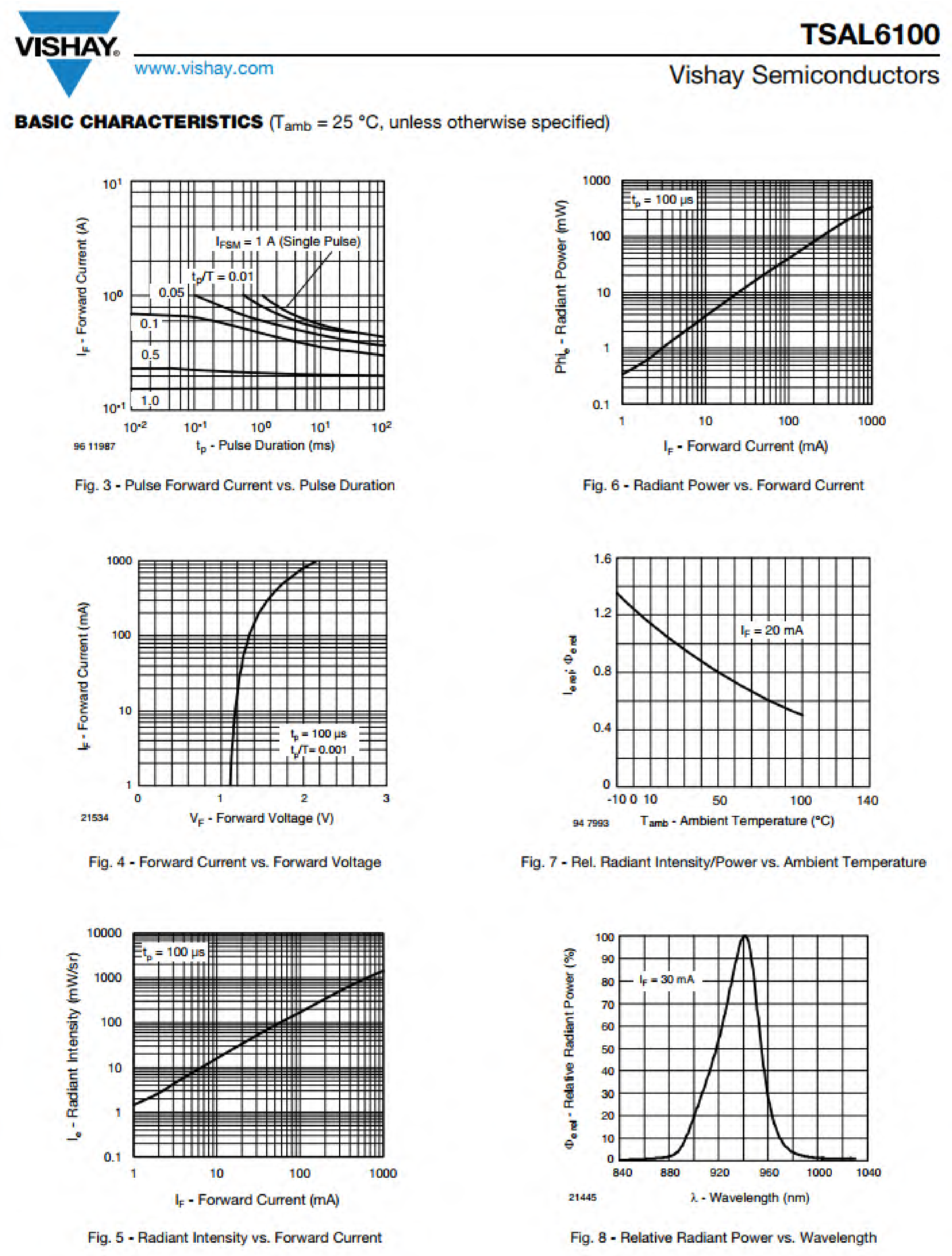


Figure 31: TSAL6100 Datasheet Screenshot 3

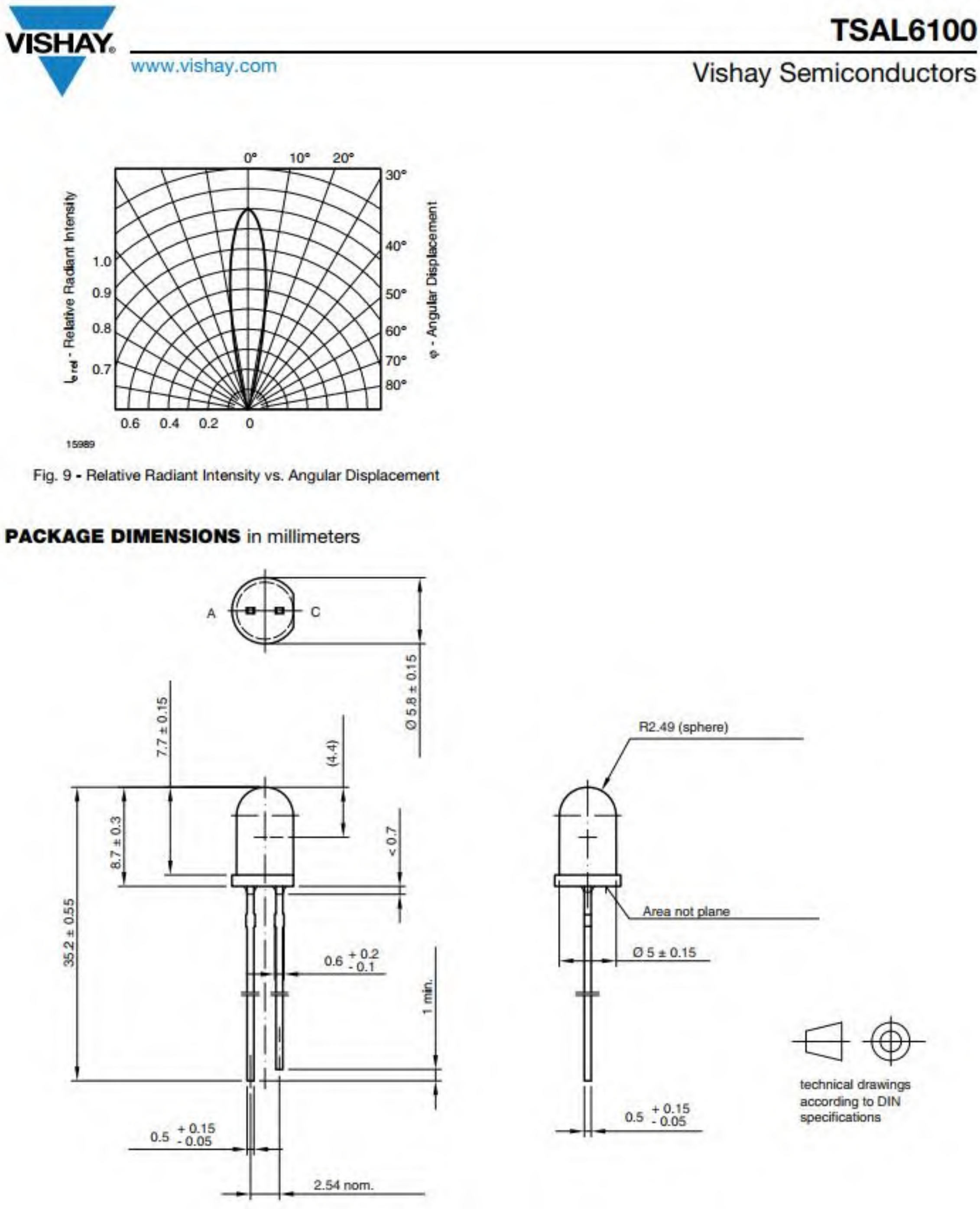


Figure 32: TSAL6100 Datasheet Screenshot 4

- IR Receiver Datasheet:

VISHAY. www.vishay.com

BPV10NF

Vishay Semiconductors

Silicon PIN Photodiode

FEATURES

- Package type: leaded
- Package form: T-1¾
- Dimensions (in mm): Ø 5
- Leads with stand-off
- High sensitivity
- Daylight blocking filter matched with 850 nm to 950 nm emitters
- Fast response times
- Angle of half sensitivity: . = ± 20°
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

Pb Pb-free e4 RoHS COMPLIANT HALOGEN FREE GREEN (5-2008)

DESCRIPTION

BPV10NF is a PIN photodiode with high speed and high sensitivity in black, T-1¾ plastic package with daylight blocking filter. Filter bandwidth is matched with 850 nm to 950 nm IR emitters.

APPLICATIONS

- High speed detector for infrared radiation
- Infrared remote control and free air data transmission systems, e.g. in combination with TSFFxxxx series IR emitters

PRODUCT SUMMARY			
COMPONENT	I_{ra} (μA) at E_e = 1.0 mW/cm², λ = 940 nm, V_R = 5.0 V	φ (°)	$λ_{0.5}$ (nm)
BPV10NF	60	± 20	780 to 1050

Note
- Test condition see table "Basic Characteristics"

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	REMARKS	PACKAGE FORM
BPV10NF	Bulk	MOQ: 4000 pcs, 4000 pcs/bulk	T-1¾
BPV10NF-CS21	Reel	MOQ: 5000 pcs, 1000 pcs/reel	T-1

Note
- MOQ: minimum order quantity

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	60	V
Power dissipation	T_{amb} ≤ 25 °C	P_V	215	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	-40 to +100	°C
Storage temperature range		T_{stg}	-40 to +100	°C
Soldering temperature	t ≤ 5 s, 2 mm from body	T_{sd}	260	°C
Thermal resistance junction to ambient	Connected with Cu wire, 0.14 mm²	R_{thJA}	350	K/W

Figure 33: BPV10NF Datasheet Screenshot 1

VISHAY.
www.vishay.com

BPV10NF
Vishay Semiconductors

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
Forward voltage	I_F = 50 mA	V_F	-	0.85	1.3	V
Breakdown voltage	I_R = 100 μA, E = 0	$V_{(BR)}$	60	-	-	V
Reverse dark current	V_R = 20 V, E = 0	I_{ro}	-	0.1	5	nA
Diode capacitance	V_R = 0 V, f = 1 MHz, E = 0	C_D	-	11	-	pF
Open circuit voltage	E_e = 1 mW/cm², λ = 850 nm	V_O	-	410	-	mV
Short circuit current	E_e = 1 mW/cm², λ = 870 nm	I_K	-	50	-	μA
Reverse light current	E_e = 1 mW/cm², λ = 870 nm, V_R = 5 V	I_{ra}	-	55	-	μA
	E_e = 1 mW/cm², λ = 940 nm, V_R = 5 V	I_{ra}	30	60	-	μA
Temperature coefficient of I_{ra}	E_e = 1 mW/cm², λ = 870 nm, V_R = 5 V	TK_{Ira}	-	-0.1	-	%/K
Absolute spectral sensitivity	V_R = 5 V, λ = 870 nm	s(λ)	-	0.55	-	A/W
Angle of half sensitivity		φ	-	± 20	-	°
Wavelength of peak sensitivity		$λ_p$	-	940	-	nm
Range of spectral bandwidth		$λ_{0.5}$	-	780 to 1050	-	nm
Quantum efficiency	λ = 950 nm	η	-	70	-	%
Noise equivalent power	V_R = 20 V, λ = 950 nm	NEP	-	3×10^{-14}	-	W/√Hz
Detectivity	V_R = 20 V, λ = 950 nm	D	-	3×10^{12}	-	cm√Hz/W
Rise time	V_R = 10 V, R_L = 50 Ω, λ = 830 nm	t_r	-	80	-	ns
Fall time	V_R = 10 V, R_L = 50 Ω, λ = 830 nm	t_f	-	60	-	ns

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

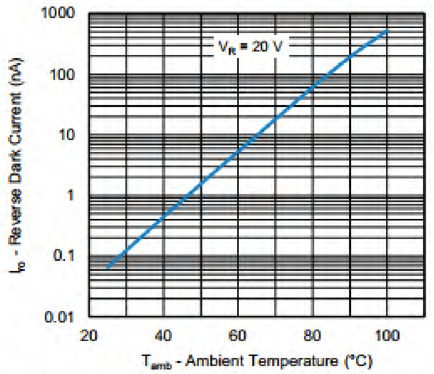


Fig. 1 - Reverse Dark Current vs. Ambient Temperature

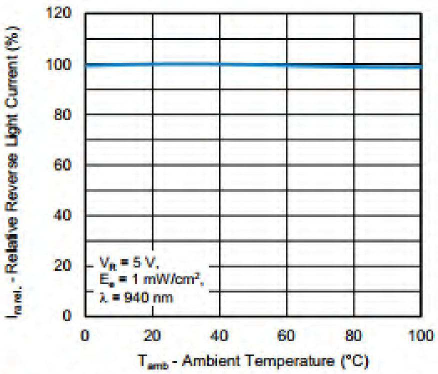


Fig. 2 - Relative Reverse Light Current vs. Ambient Temperature

Figure 34: BPV10NF Datasheet Screenshot 2

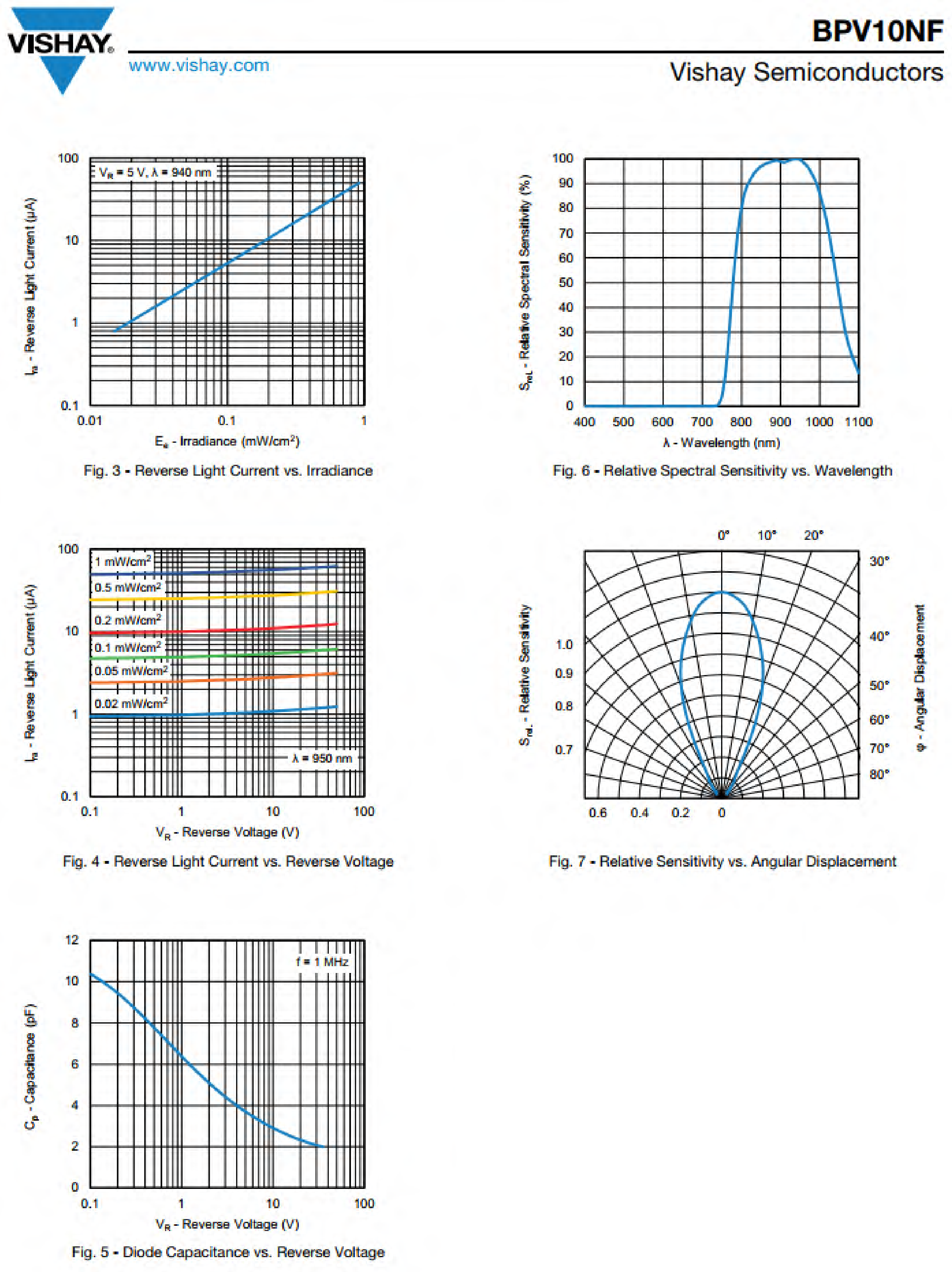

VISHAY.
www.vishay.com
BPV10NF
Vishay Semiconductors

Fig. 3 - Reverse Light Current vs. Irradiance

Fig. 6 - Relative Spectral Sensitivity vs. Wavelength

Fig. 4 - Reverse Light Current vs. Reverse Voltage

Fig. 7 - Relative Sensitivity vs. Angular Displacement

Fig. 5 - Diode Capacitance vs. Reverse Voltage

Figure 35: BPV10NF Datasheet Screenshot 3

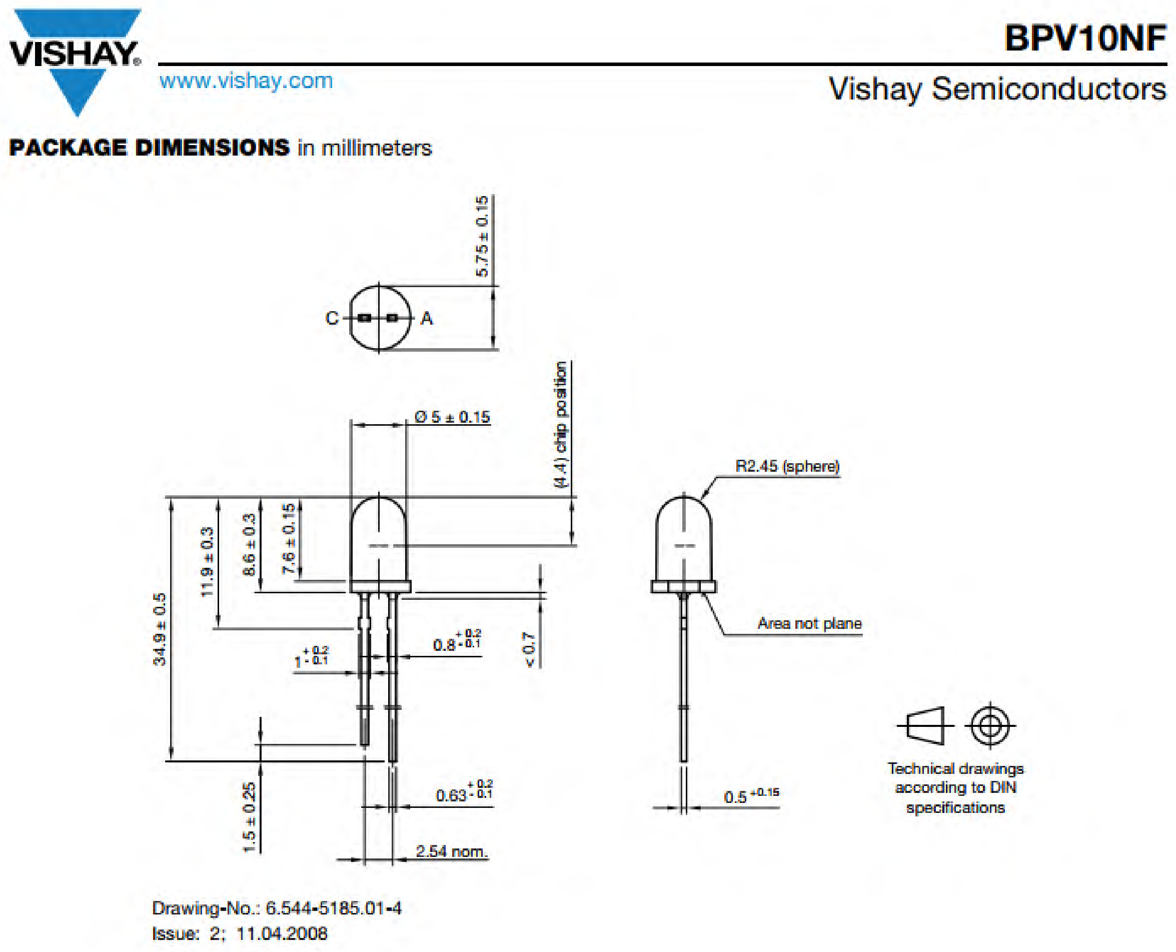


Figure 36: BPV10NF Datasheet Screenshot 4

- *2N2222A NPN BJT datasheet:*

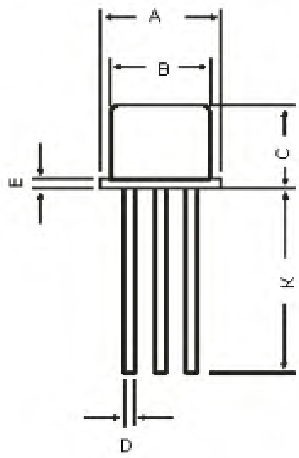
2N2222A
High Speed Switching Transistor

multicomp

Features:

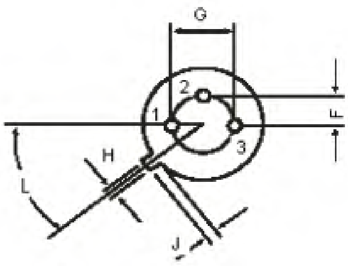
- NPN Silicon Planar Switching Transistor.
- Fast switching devices exhibiting short turn-off and low saturation voltage characteristics.
- Switching and Linear application DC and VHF Amplifier applications.

TO-18 Metal Can Package



Dimensions	Minimum	Maximum
A	5.24	5.84
B	4.52	4.97
C	4.31	5.33
D	0.4	0.53
E	—	0.76
F	—	1.27
G	—	2.97
H	0.91	1.17
J	0.71	1.21
K	12.7	—
L	45°	

Dimensions : Millimetres



Pin Configuration:
1. Emitter
2. Base
3. Collector

Figure 37: 2N2222A Datasheet Screenshot 1

2N2222A

High Speed Switching Transistors

multicomp

Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit
Collector-Emitter Voltage	V_{CEO}	40	V
Collector-Base Voltage	V_{CBO}	75	
Emitter-Base Voltage	V_{EBO}	6.0	
Collector Current Continuous	I_C	800	mA
Power Dissipation at T_a = 25°C Derate above 25°C	P_D	500 2.28	mW mW/°C
Power Dissipation at T_C= 25°C Derate above 25°C	P_D	1.2 6.85	W mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

Electrical Characteristics (T_a = 25°C unless otherwise specified)

Parameter	Symbol	Test Condition	Value		
			Minimum	Maximum	Unit
Collector-Emitter Voltage	V_{CEO}	I_C = 10mA, I_B = 0	40	-	V
Collector-Base Voltage	V_{CBO}	I_C = 10µA, I_E = 0	75	-	
Emitter-Base Voltage	V_{EBO}	I_E = 10µA, I_C = 0	6.0	-	
Collector-Cut off Current	I_{CBO}	V_{CB} = 60V, I_E = 0	-	10	nA
		T_a = 150°C V_{CB} = 60V, I_E = 0		10	µA
	I_{CEX}	V_{CE} = 60V, V_{EB} = 3V		10	nA
Emitter-Cut off Current	I_{EBO}	V_{EB} = 3V, I_C = 0	-	10	nA
Base-Cut off Current	I_{BL}	V_{CE} = 60V, V_{EB} = 3V	-	20	
Collector Emitter Saturation Voltage	*$V_{CE(Sat)}$	I_C = 150mA, I_B = 15mA	-	0.3	V
		I_C = 500mA, I_B = 50mA	-	1.0	
Base Emitter Saturation Voltage	*$V_{BE(Sat)}$	I_C = 150mA, I_B = 15mA	-	0.6-1.2	
		I_C = 500mA, I_B = 50mA	-	2.0	

Figure 38: 2N2222A Datasheet Screenshot 2

2N2222A

High Speed Switching Transistors

multicomp

Electrical Characteristics (T_a = 25°C unless otherwise specified)

Parameter	Symbol	Test Condition	Rating	Unit
DC Current Gain	h_{FE}	I_C = 0.1mA, V_{CE} = 10V I_C = 1mA, V_{CE} = 10V I_C = 10mA, V_{CE} = 10V T_a = 55°C I_C = 10mA, V_{CE} = 10V I_C = 150mA, V_{CE} = 10V I_C = 150mA, V_{CE} = 1V I_C = 500mA, V_{CE} = 10V	>35 >50 >75 >35 100-300 >50 >40	-
Dynamic Characteristics				
		ALL F = 1kHz		
Small Signal Current Gain	h_{fe}	I_C = 1mA, V_{CE} = 10V I_C = 10mA, V_{CE} = 10V	50 - 300 75 - 375	-
Input Impedance	h_{ie}	I_C = 1mA, V_{CE} = 10V I_C = 10mA, V_{CE} = 10V	2.0-8.0 0.25-1.25	kΩ
Voltage Feedback Ratio	h_{re}	I_C = 1mA, V_{CE} = 10V I_C = 10mA, V_{CE} = 10V	<8.0 <4.0	x10-4
Output Admittance	h_{oe}	I_C = 1mA, V_{CE} = 10V I_C = 10mA, V_{CE} = 10V	5.0-35 25-200	umhos
Collector Base Time Constant	rb'Cc	I_E = 20mA, V_{CB} = 20V f = 31.8MHz	<150	ps
Real Part Common-Emitter High Frequency	$Re_{(hie)}$	I_C = 20mA, V_{CE} = 20V	<60	Ω
Input Impedance	-	f = 300MHz	-	-
Noise Figure	N_F	I_C = 100µA, V_{CE} = 10V Rs = 1kohms, f = 1kHz	<4.0	dB
Dynamic Characteristics				
Transistors Frequency	f_t	I_C = 20mA, V_{CE} = 20V f = 100MHz	>300	MHz
Output Capacitance	C_{ob}	V_{CB} = 10V, I_E = 0 f = 100kHz	<8.0	pF
Input Capacitance	C_{ib}	V_{EB} = 0.5V, I_C = 0 f = 100kHz	<25	pF
Switching Time				
Delay Time Rise Time	t_d t_r	I_C = 150mA,I_{B1} = 15mA V_{CC} = 30V, V_{BE} = 0.5V	<10 <25	ns
Storage Time Fall Time	t_s t_f	I_C = 150mA, I_{B1} = I_{B2} = 15mA, V_{CC} = 30V	<225 <60	ns

*Pulse Condition: Pulse Width = 300µs, Duty Cycle = 2%

Specifications

V_{CEO} maximum (V)	I_C maximum (A)	$V_{CE(sat)}$ maximum (V) at I_C = 150mA	t_{off} maximum (ns) at I_C = 150mA	h_{FE} minimum at I_C = 150mA	P_{tot} at 25°C (mW)	Package and Pin Out	Part Number
40	0.8	0.3	60	100	500	TO-18	2N2222A

Figure 39: 2N2222A Datasheet Screenshot 3

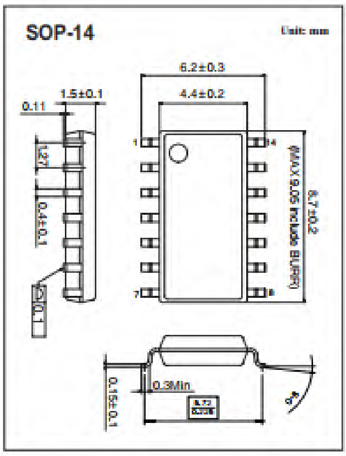
- LM339 quad comparator datasheet:

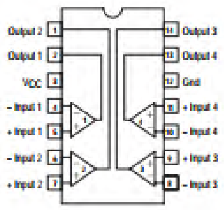
LGE

Quad Single Supply Comparators
LM339

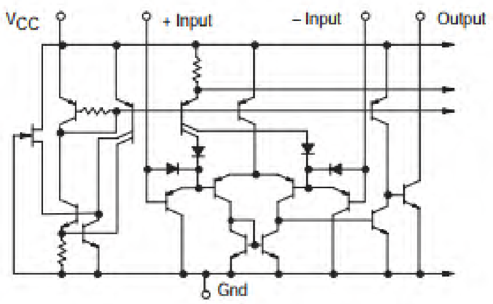
Features

- Single or Split Supply Operation
- Low Input Bias Current: 25 nA (Typ)
- Low Input Offset Current: ±5.0 nA (Typ)
- Input Common Mode Voltage Range to Gnd
- Low Output Saturation Voltage: 130 mV (Typ) @ 4.0 mA
- TTL and CMOS Compatible





Circuit Schematic



Absolute Maximum Ratings Ta = 25℃

Parameter	Symbol	Rating	Unit
Power Supply Voltage	Vcc	+36 or ±18	V
Input Differential Voltage Range	VIDR	36	V
Input Common Mode Voltage Range	VICR	-0.3 to Vcc	V
Output Short Circuit-to-Ground *	Isc	Continuous	
Power Dissipation @ TA = 25℃ Derate above 25℃ Plastic Package	PD	8.0 1.0	mW/℃ W
Operating Ambient Temperature Range	TA	0 to 70	℃
Junction Temperature	TJ	150	℃
Storage Temperature Range	Tstg	-65 to +150	℃

* The maximum output current may be as high as 20 mA, independent of the magnitude of Vcc, output short circuits to Vcc can cause excessive heating and eventual destruction.

Figure 40: LM339 Datasheet Screenshot 1

LGE

LM339

■ Electrical Characteristics (V_{CC} = +5.0 V, T_A =25℃, unless otherwise noted.)

Parameter	Symbol	Testconditons	Min	Typ	Max	Unit
Input Offset Voltage *4	V_{IO}			±2.0	±5.0	mV
Input Bias Current *4,5	I_{IB}			25	250	nA
Input Offset Current *4	I_{IO}			±5.0	±50	nA
Input Common Mode Voltage Range	V_{ICMR}		0		Vcc-1.5	V
Supply Current	I_{CC}	R_L = ∞(For All Comparators)		0.8	2.0	mA
		R_L = ∞, Vcc = 30 V		1.0	2.5	
Voltage Gain	A_{VOL}	R_L≥15 kΩ, Vcc = 15 V	50	200		V/mV
Large Signal Response Time		V_I = TTL Logic Swing,V_{ref} = 1.4 V, V_{RL} = 5.0 V,R_L = 5.1 KΩ		300		ns
Response Time *6		V_{RL} = 5.0 V, R_L = 5.1 kΩ		1.3		μs
Output Sink Current	I_{Sink}	V_I (-)≥+1.0 V, V_I(+) = 0,V_O ≤ 1.5 V	6.0	16		mA
Saturation Voltage	V_{sat}	V_I(-) ≥+1.0 V, V_I(+) = 0,I_{sink} ≤4.0 mA		130	400	mV
Output Leakage Current	I_{OL}	V_I(+) ≥+1.0 V, V_I(-) = 0,V_O = +5.0 V		0.1		nA

■ Performance Characteristics (V_{CC}=+5.0V,0℃≤T_A≤70℃)

Parameter	Symbol	Testconditons	Min	Typ	Max	Unit
Input Offset Voltage *4	V_{IO}				±9.0	mV
Input Bias Current*4,5	I_{IB}				400	nA
Input Offset Current *4	I_{IO}				±150	nA
Input Common Mode Voltage Range	V_{ICMR}		0		Vcc-2.0	V
Saturation Voltage	V_{sat}	V_I(-) ≥ +1.0 V, V_I(+) = 0,I_{sink} ≤ 4.0 mA			700	mV
Output Leakage Current	I_{OL}	V_I(+)≥ +1.0 V, V_I(-) = 0,VO = 30 V			1.0	μA
Differential Input Voltage	V_{ID}	All VI≥ 0 V			Vcc	V

*4. At the output switch point, V≈ 1.4 V, Rs ≤ 100 Ω 5.0 V ≤ Vcc ≤ 30 V, with the inputs over the full common mode range (0 V to Vcc -1.5 V).

*5. The bias current flows out of the inputs due to the PNP input stage. This current is virtually constant, independent of the output state.

*6. The response time specified is for a 100 mV input step with 5.0 mV overdrive. For larger signals, 300 ns is typical.

Figure 41: LM339 Datasheet Screenshot 2

- SRD-12VDC-SL-C relay datasheet:

SRD Series SUBMINATURE HIGH POWER RELAY 7A/10A/15A

c US
E167996
R50056114
R50137084
CQC
CQC08002027667

RoHS Compliant

Features

- Miniature volume, PCB usage
- Contact rating: 7A/10A/15A
- Temperature range: +85°C/+105°C

Ordering Information

SRD-12VDC-S L-C

- A / B / C — Contact arrangment
- L0. 36W / D0. 45W — Coil Power
- S sealed / F dustproof — Construction
- 5V / 6V / 9V / 12V 18V / 24V / 36V / 48V — Coil Voltage
- Part number

Contact Rating

Contact a rrangment	1A(spstno)/1B(Spstnc)/1C(Spdt)
Contact resistance	100mΩ (1A 6VDC)
Contact material	Silver alloy : AgCdO、AgSnO2、AgNi
Contact rating	7A/250VAC 10A/250VAC 15A/250VAC
Max switching voltage	250VAC
Max switching current	15A
Max switching power	3750VA
Electrical endurance (frequency: 1800 ops/h)	$1x10^5$ops / $1x10^4$ops
Mechanical endurance (frequency: 18000 ops/h)	$1x10^7$ops

Characteristics

Insulation system		Class B / Class F
Insulation resistance		100MΩ(500VDC)
Dielectric Strength Leakage current 1mA	Between contacts and coil	1500VAC 1minute
	Between open contacts	1000VAC 1minute
Operate time(Under nominal voltage)		≤10ms
Release time(Under nominal voltage)		≤10ms
Humidity		85% RH (20°C)
Ambient Temperature		-40°C~+85°C/-40°C~+105°C
Shock resistance	Functional	98m/s²
	Destructive	980m/s²
Vibration resistance (Double amplitude)		10Hz~55Hz 1.5mm
Weight		Approx 9g
Construction		Sealed

Remark:1)All above data is initial value

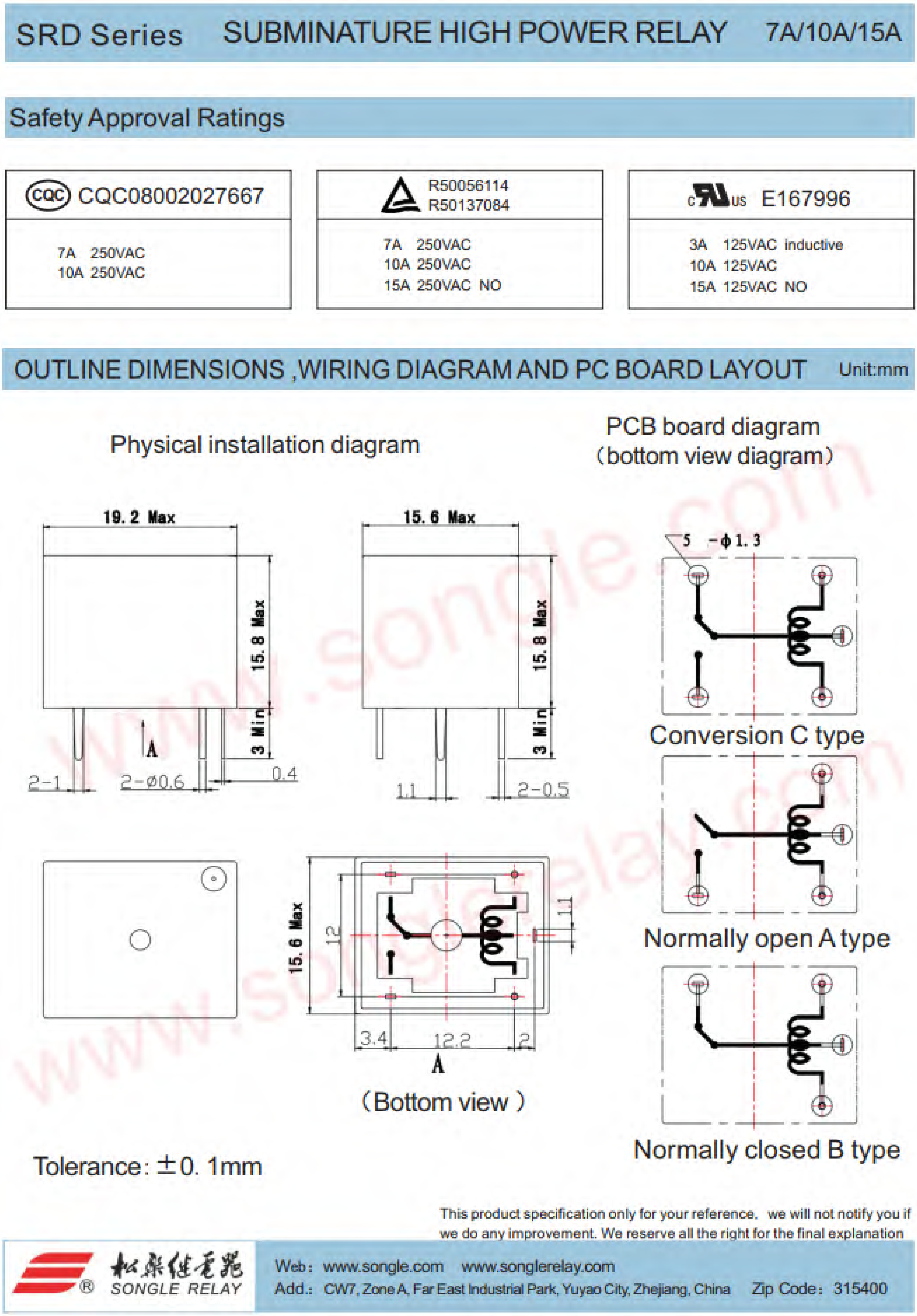
Coil Data (at 20°C)

Power dissipation W	Voltage VDC	Current mA	Resistance Ω±10%	Pick-up voltage	Drop-out voltage	Max allowable
0.36W (L)	05	71.4	70	75%Max	10%Min	130%
	06	60	100			
	09	40	225			
	12	30	400			
	18	20	900			
	24	15	1600			
	36	10	3600			
	48	7.5	6400			
0.45W (D)	05	89.3	55	75%Max	10%Min	130%
	06	75	80			
	09	50	180			
	12	37.5	320			
	18	25	720			
	24	18.7	1280			
	36	12.5	2880			
	48	10	4500			

This product specification only for your reference, we will not notify you if we do any improvement. We reserve all the right for the final explanation

松乐继电器 SONGLE RELAY
Web: www.songle.com www.songlerelay.com
Add.: CW7, Zone A, Far East Industrial Park, Yuyao City, Zhejiang, China Zip Code: 315400

Figure 42: SRD-12VDC-SL-C Datasheet Screenshot 1



SRD Series SUBMINATURE HIGH POWER RELAY 7A/10A/15A

Safety Approval Ratings

CQC CQC08002027667	R50056114 R50137084	c UL us E167996
7A 250VAC 10A 250VAC	7A 250VAC 10A 250VAC 15A 250VAC NO	3A 125VAC inductive 10A 125VAC 15A 125VAC NO

OUTLINE DIMENSIONS ,WIRING DIAGRAM AND PC BOARD LAYOUT Unit:mm

This product specification only for your reference, we will not notify you if we do any improvement. We reserve all the right for the final explanation

松乐继电器 SONGLE RELAY

Web: www.songle.com www.songlerelay.com

Add.: CW7, Zone A, Far East Industrial Park, Yuyao City, Zhejiang, China Zip Code: 315400

Figure 43: SRD-12VDC-SL-C Datasheet Screenshot 2

- 555 timer datasheet:

HARRIS SEMICONDUCTOR

CA555, CA555C, LM555, LM555C, NE555

Timers for Timing Delays and Oscillator Application in Commercial, Industrial and Military Equipment

May 1997

Features

- Accurate Timing From Microseconds Through Hours
- Astable and Monostable Operation
- Adjustable Duty Cycle
- Output Capable of Sourcing or Sinking up to 200mA
- Output Capable of Driving TTL Devices
- Normally ON and OFF Outputs
- High Temperature Stability . . . . 0.005%/^{o}C
- Directly Interchangeable with SE555, NE555, MC1555, and MC1455

Applications

- Precision Timing
- Sequential Timing
- Time Delay Generation
- Pulse Generation
- Pulse Detector
- Pulse Width and Position Modulation

Ordering Information

PART NUMBER (BRAND)	TEMP. RANGE (^{o}C)	PACKAGE	PKG. NO.
CA0555E	-55 to 125	8 Ld PDIP	E8.3
CA0555M (555)	-55 to 125	8 Ld SOIC	M8.15
CA0555M96 (555)	-55 to 125	8 Ld SOIC †	M8.15
CA0555T	-55 to 125	8 Pin Metal Can	T8.C
CA0555CE	0 to 70	8 Ld PDIP	E8.3
CA0555CM (555C)	0 to 70	8 Ld SOIC	M8.15
CA0555CM96 (555C)	0 to 70	8 Ld SOIC †	M8.15
CA0555CT	0 to 70	8 Pin Metal Can	T8.C
LM555N	-55 to 125	8 Ld PDIP	E8.3
LM555CN	0 to 70	8 Ld PDIP	E8.3
NE555N	0 to 70	8 Ld PDIP	E8.3

NOTE: † Denotes Tape and Reel

Description

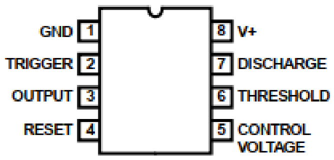
The CA555 and CA555C are highly stable timers for use in precision timing and oscillator applications. As timers, these monolithic integrated circuits are capable of producing accurate time delays for periods ranging from microseconds through hours. These devices are also useful for astable oscillator operation and can maintain an accurately controlled free running frequency and duty cycle with only two external resistors and one capacitor.

The circuits of the CA555 and CA555C may be triggered by the falling edge of the waveform signal, and the output of these circuits can source or sink up to a 200mA current or drive TTL circuits.

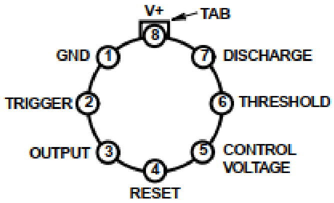
These types are direct replacements for industry types in packages with similar terminal arrangements e.g. SE555 and NE555, MC1555 and MC1455, respectively. The CA555 type circuits are intended for applications requiring premium electrical performance. The CA555C type circuits are intended for applications requiring less stringent electrical characteristics.

Pinouts

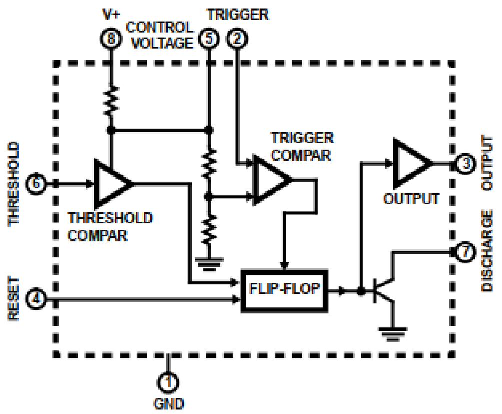
CA555, CA555C (PDIP, SOIC)
LM555, LM555C, NE555 (PDIP)
TOP VIEW



CA555, CA555C (METAL CAN)
TOP VIEW



Functional Block Diagram



8-3

File Number 834.4

Figure 44: 555 Timer Datasheet Screenshot 1

CA555, CA555C, LM555, LM555C, NE555

Absolute Maximum Ratings

DC Supply Voltage 18V

Operating Conditions

Temperature Range
- CA555, LM555 . . . . -55°C to 125°C
- CA555C, LM555C, NE555 . . . . 0°C to 70°C

Thermal Information

Thermal Resistance (Typical, Note 1)	θ_{JA} (°C/W)	θ_{JC} (°C/W)
Metal Can Package	170	85
PDIP Package	100	N/A
SOIC Package	160	N/A

Maximum Junction Temperature (Hermetic Package) . . . . 175°C
Maximum Junction Temperature (Plastic Package) . . . . 150°C
Maximum Storage Temperature Range . . . . -65°C to 150°C
Maximum Lead Temperature (Soldering 10s) . . . . 300°C
(SOIC - Lead Tips Only)

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:
1. θ_{JA} is measured with the component mounted on an evaluation PC board in free air.

Electrical Specifications

T_A = 25°C, V+ = 5V to 15V Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS	CA555, LM555			CA555C, LM555C, NE555			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
DC Supply Voltage	V+		4.5	-	18	4.5	-	16	V
DC Supply Current (Low State), (Note 2)	I+	V+ = 5V, $R_L = \infty$	-	3	5	-	3	6	mA
		V+ = 15V, $R_L = \infty$	-	10	12	-	10	15	mA
Threshold Voltage	V_{TH}		-	($^2/_3$)V+	-	-	($^2/_3$)V+	-	V
Trigger Voltage		V+ = 5V	1.45	1.67	1.9	-	1.67	-	V
		V+ = 15V	4.8	5	5.2	-	5	-	V
Trigger Current			-	0.5	-	-	0.5	-	µA
Threshold Current (Note 3)	I_{TH}		-	0.1	0.25	-	0.1	0.25	µA
Reset Voltage			0.4	0.7	1.0	0.4	0.7	1.0	V
Reset Current			-	0.1	-	-	0.1	-	mA
Control Voltage Level		V+ = 5V	2.9	3.33	3.8	2.6	3.33	4	V
		V+ = 15V	9.6	10	10.4	9	10	11	V
Output Voltage Low State	V_{OL}	V+ = 5V, I_{SINK} = 5mA	-	-	-	-	0.25	0.35	V
		I_{SINK} = 8mA	-	0.1	0.25	-	-	-	V
		V+ = 15V, I_{SINK} = 10mA	-	0.1	0.15	-	0.1	0.25	V
		I_{SINK} = 50mA	-	0.4	0.5	-	0.4	0.75	V
		I_{SINK} = 100mA	-	2.0	2.2	-	2.0	2.5	V
		I_{SINK} = 200mA	-	2.5	-	-	2.5	-	V
Output Voltage High State	V_{OH}	V+ = 5V, I_{SOURCE} = 100mA	3.0	3.3	-	2.75	3.3	-	V
		V+ = 15V, I_{SOURCE} = 100mA	13.0	13.3	-	12.75	13.3	-	V
		I_{SOURCE} = 200mA	-	12.5	-	-	12.5	-	V
Timing Error (Monostable)		R_1, R_2 = 1kΩ to 100kΩ, C = 0.1µF Tested at V+ = 5V, V+ = 15V	-	0.5	2	-	1	-	%
Frequency Drift with Temperature			-	30	100	-	50	-	ppm/°C
Drift with Supply Voltage			-	0.05	0.2	-	0.1	-	%/V

8-4

Figure 45: 555 Timer Datasheet Screenshot 2

CA555, CA555C, LM555, LM555C, NE555

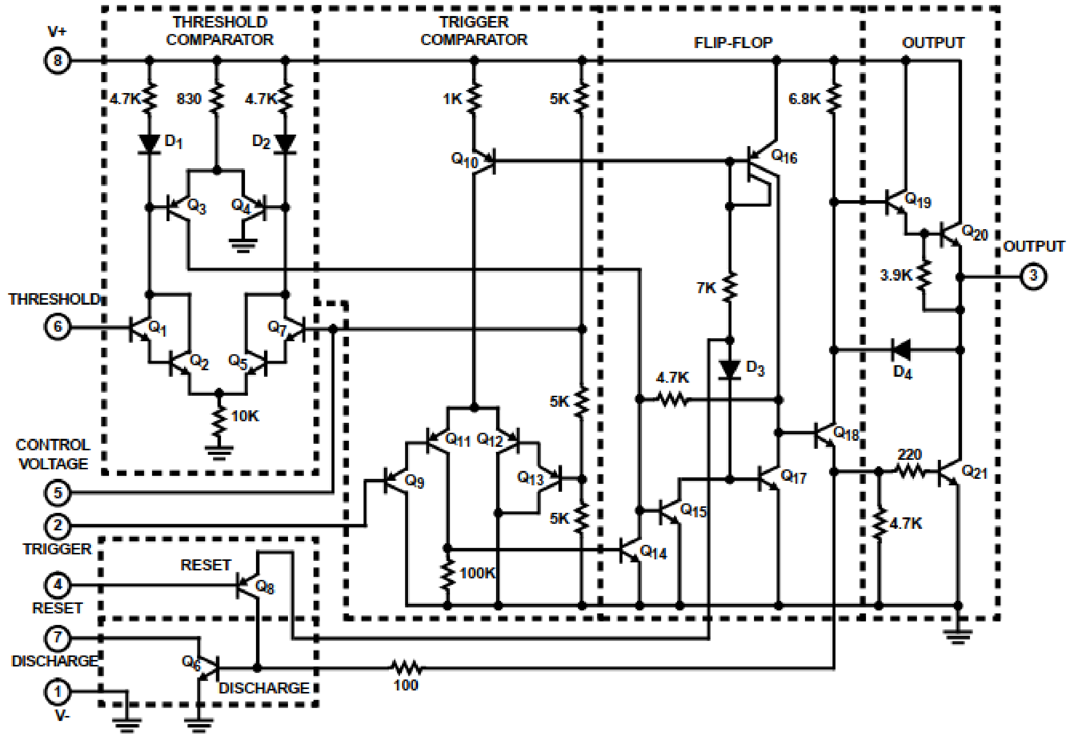
Electrical Specifications $T_A = 25^oC$, V+ = 5V to 15V Unless Otherwise Specified **(Continued)**

PARAMETER	SYMBOL	TEST CONDITIONS	CA555, LM555			CA555C, LM555C, NE555			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Rise Time	t_R		-	100	-	-	100	-	ns
Output Fall Time	t_F		-	100	-	-	100	-	ns

NOTES:

2. When the output is in a high state, the DC supply current is typically 1mA less than the low state value.
3. The threshold current will determine the sum of the values of R_1 and R_2 to be used in Figure 4 (astable operation); the maximum total $R_1 + R_2 = 20M\Omega$.

Schematic Diagram



NOTE: Resistance values are in ohms.

Typical Applications

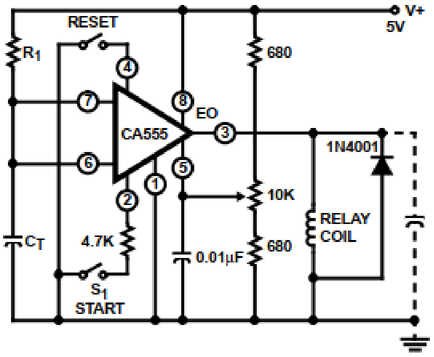
Reset Timer (Monostable Operation)

Figure 1 shows the CA555 connected as a reset timer. In this mode of operation capacitor C_T is initially held discharged by a transistor on the integrated circuit. Upon closing the “start” switch, or applying a negative trigger pulse to terminal 2, the integral timer flip-flop is “set” and releases the short circuit across C_T which drives the output voltage “high” (relay energized). The action allows the voltage across the capacitor to increase exponentially with the constant $t = R_1C_T$. When the voltage across the capacitor equals 2/3 V+, the comparator resets the flip-flop which in turn discharges the capacitor rapidly and drives the output to its low state.

8-5

Figure 46: 555 Timer Datasheet Screenshot 3

CA555, CA555C, LM555, LM555C, NE555



NOTE: All resistance values are in ohms.

FIGURE 1. RESET TIMER (MONOSTABLE OPERATION)

Since the charge rate and threshold level of the comparator are both directly proportional to V+, the timing interval is relatively independent of supply voltage variations. Typically, the timing varies only 0.05% for a 1V change in V+.

Applying a negative pulse simultaneously to the reset terminal (4) and the trigger terminal (2) during the timing cycle discharges C_T and causes the timing cycle to restart. Momentarily closing only the reset switch during the timing interval discharges C_T, but the timing cycle does not restart.

Figure 2 shows the typical waveforms generated during this mode of operation, and Figure 3 gives the family of time delay curves with variations in R_1 and C_T.

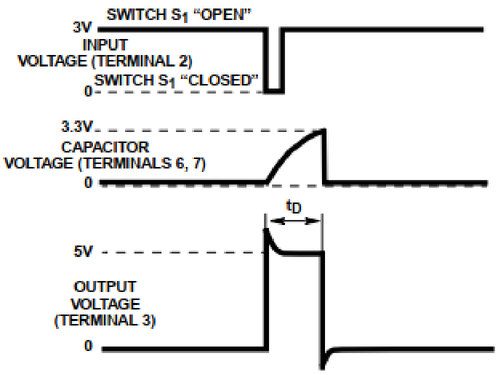


FIGURE 2. TYPICAL WAVEFORMS FOR RESET TIMER

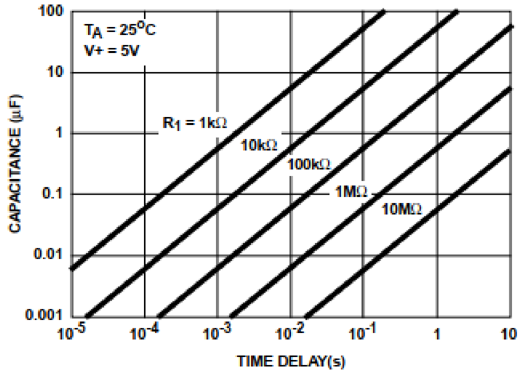


FIGURE 3. TIME DELAY vs RESISTANCE AND CAPACITANCE

Repeat Cycle Timer (Astable Operation)

Figure 4 shows the CA555 connected as a repeat cycle timer. In this mode of operation, the total period is a function of both R_1 and R_2.

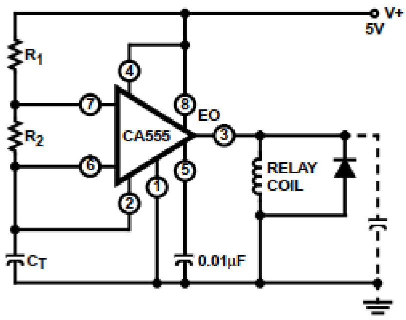


FIGURE 4. REPEAT CYCLE TIMER (ASTABLE OPERATION)

$$T = 0.693\,(R_1 + 2R_2)\,C_T = t_1 + t_2$$

where $t_1 = 0.693\,(R_1 + R_2)\,C_T$

and $t_2 = 0.693\,(R_2)\,C_T$

the duty cycle is:

$$\frac{t_1}{t_1 + t_2} = \frac{R_1 + R_2}{R_1 + 2R_2}$$

Typical waveforms generated during this mode of operation are shown in Figure 5. Figure 6 gives the family of curves of free running frequency with variations in the value of $(R_1 + 2R_2)$ and C_T.

8-6

Figure 47: 555 Timer Datasheet Screenshot 4

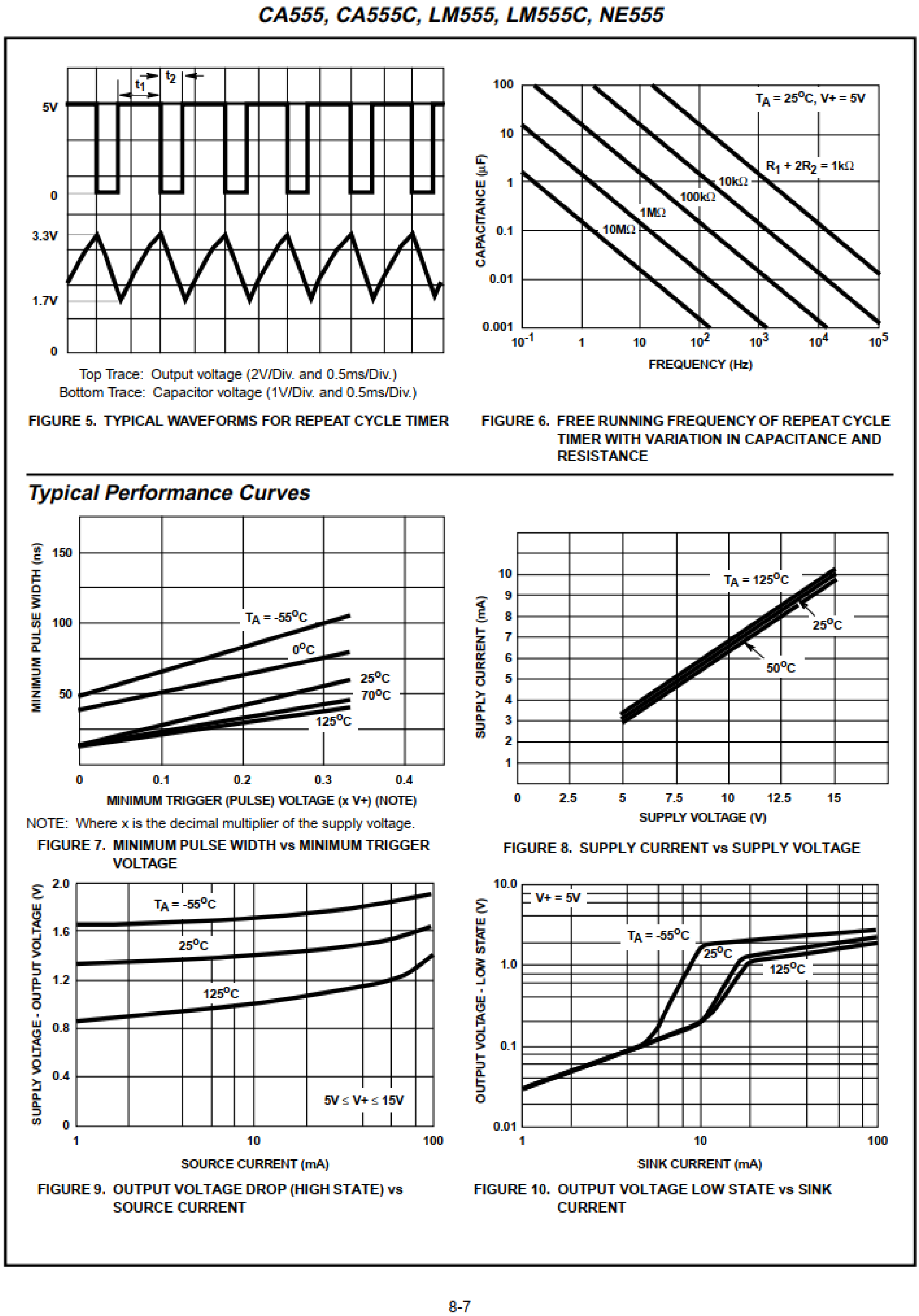

CA555, CA555C, LM555, LM555C, NE555

FIGURE 5. TYPICAL WAVEFORMS FOR REPEAT CYCLE TIMER

FIGURE 6. FREE RUNNING FREQUENCY OF REPEAT CYCLE TIMER WITH VARIATION IN CAPACITANCE AND RESISTANCE

Typical Performance Curves

NOTE: Where x is the decimal multiplier of the supply voltage.

FIGURE 7. MINIMUM PULSE WIDTH vs MINIMUM TRIGGER VOLTAGE

FIGURE 8. SUPPLY CURRENT vs SUPPLY VOLTAGE

FIGURE 9. OUTPUT VOLTAGE DROP (HIGH STATE) vs SOURCE CURRENT

FIGURE 10. OUTPUT VOLTAGE LOW STATE vs SINK CURRENT

8-7

Figure 48: 555 Timer Datasheet Screenshot 5

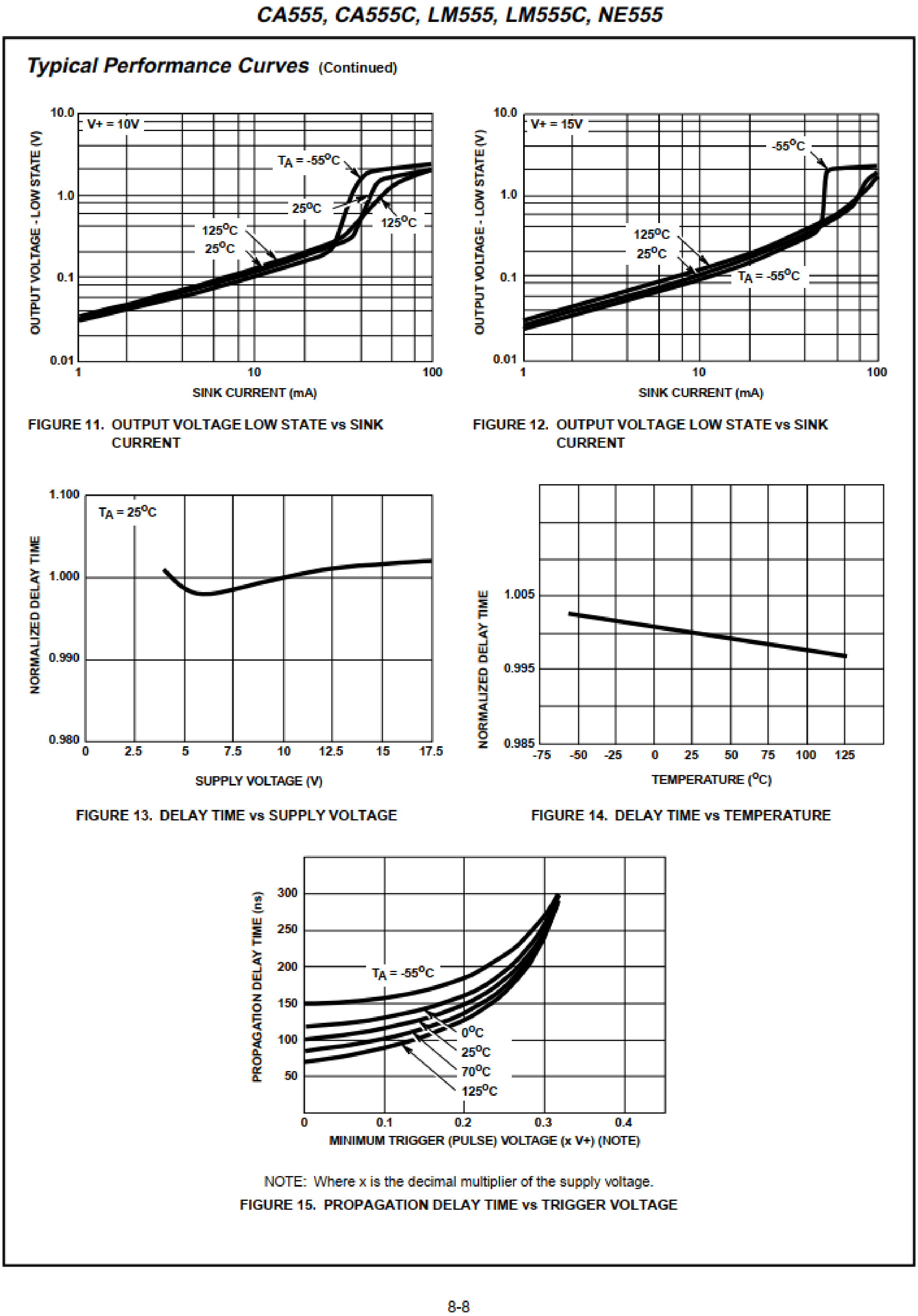
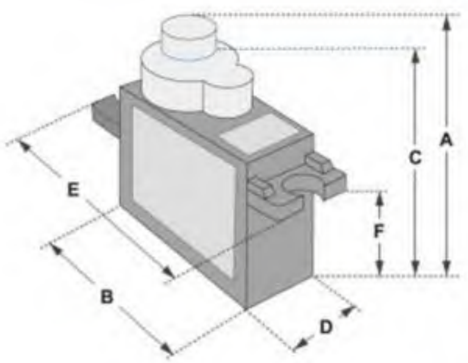


Figure 49: 555 Timer Datasheet Screenshot 6

- SG90 micro servomotor datasheet:

SERVO MOTOR SG90 **DATA SHEET**

Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good 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. It comes with a 3 horns (arms) and hardware.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6

Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is middle, is all the way to the right, "-90" (~1ms pulse) is all the way to the left.

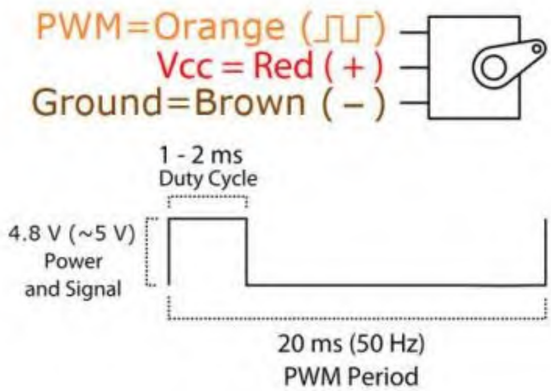


Figure 50: SG90 Micro Servomotor Datasheet Screenshot

- IC 7473 dual JK flip-flop datasheet:

FAIRCHILD
SEMICONDUCTOR™

September 1986
Revised February 2000

DM7473 Dual Master-Slave J-K Flip-Flops with Clear and Complementary Outputs

DM7473
Dual Master-Slave J-K Flip-Flops with Clear and Complementary Outputs

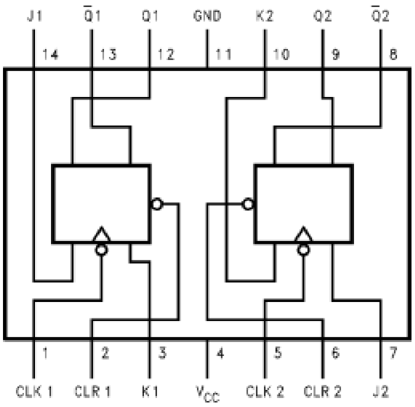
General Description

This device contains two independent positive pulse triggered J-K flip-flops with complementary outputs. The J and K data is processed by the flip-flops after a complete clock pulse. While the clock is LOW the slave is isolated from the master. On the positive transition of the clock, the data from the J and K inputs is transferred to the master. While the clock is HIGH the J and K inputs are disabled. On the negative transition of the clock, the data from the master is transferred to the slave. The logic states of the J and K inputs must not be allowed to change while the clock is HIGH. Data transfers to the outputs on the falling edge of the clock pulse. A LOW logic level on the clear input will reset the outputs regardless of the logic states of the other inputs.

Ordering Code:

Order Number	Package Number	Package Description
DM7473N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Connection Diagram



Function Table

Inputs				Outputs	
CLR	CLK	J	K	Q	$\overline{Q}$
L	X	X	X	L	H
H	⎍	L	L	Q_0	$\overline{Q}_0$
H	⎍	H	L	H	L
H	⎍	L	H	L	H
H	⎍	H	H	Toggle	

H = HIGH Logic Level
L = LOW Logic Level
X = Either LOW or HIGH Logic Level
⎍ = Positive pulse data. the J and K inputs must be held constant while the clock is HIGH. Data is transferred to the outputs on the falling edge of the clock pulse.
Q_0 = The output logic level before the indicated input conditions were established.
Toggle = Each output changes to the complement of its previous level on each HIGH level clock pulse.

 DS006525 www.fairchildsemi.com

Figure 51: IC 7473 Dual JK Flip-Flip Datasheet Screenshot 1

DM7473

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	5.5V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter		Min	Nom	Max	Units
V_{CC}	Supply Voltage		4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage		2			V
V_{IL}	LOW Level Input Voltage				0.8	V
I_{OH}	HIGH Level Output Current				−0.4	mA
I_{OL}	LOW Level Output Current				16	mA
f_{CLK}	Clock Frequency (Note 3)		0		15	MHz
t_W	Pulse Width	Clock HIGH	20			
	(Note 3)	Clock LOW	47			ns
		Clear LOW	25			
t_{SU}	Input Setup Time (Note 2)(Note 3)		0↑			ns
t_H	Input Hold Time (Note 2)(Note 3)		0↓			ns
T_A	Free Air Operating Temperature		0		70	°C

Note 2: The symbol (↑, ↓) indicates the edge of the clock pulse is used for reference: (↑) for rising edge, (↓) for falling edge.

Note 3: $T_A = 25°C$ and $V_{CC} = 5V$.

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 4)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −12 mA				−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max V_{IL} = Max, V_{IH} = Min		2.4	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IH} = Min, V_{IL} = Max			0.2	0.4	V
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 5.5V				1	mA
I_{IH}	HIGH Level	V_{CC} = Max	J, K			40	
	Input Current	V_I = 2.4V	Clock			80	μA
			Clear			80	
I_{IL}	LOW Level Input	V_{CC} = Max	J, K			−1.6	
	Current	V_I = 0.4V	Clock			−3.2	mA
			Clear			−3.2	
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 5)		−18		−55	mA
I_{CC}	Supply Current	V_{CC} = Max, (Note 6)			18	34	mA

Note 4: All typicals are at $V_{CC} = 5V$, $T_A = 25°C$.

Note 5: Not more than one output should be shorted at a time.

Note 6: With all outputs OPEN, I_{CC} is measured with the Q and $\overline{Q}$ outputs HIGH in turn. At the time of measurement the clock input grounded.

Switching Characteristics at $V_{CC} = 5V$ and $T_A = 25°C$

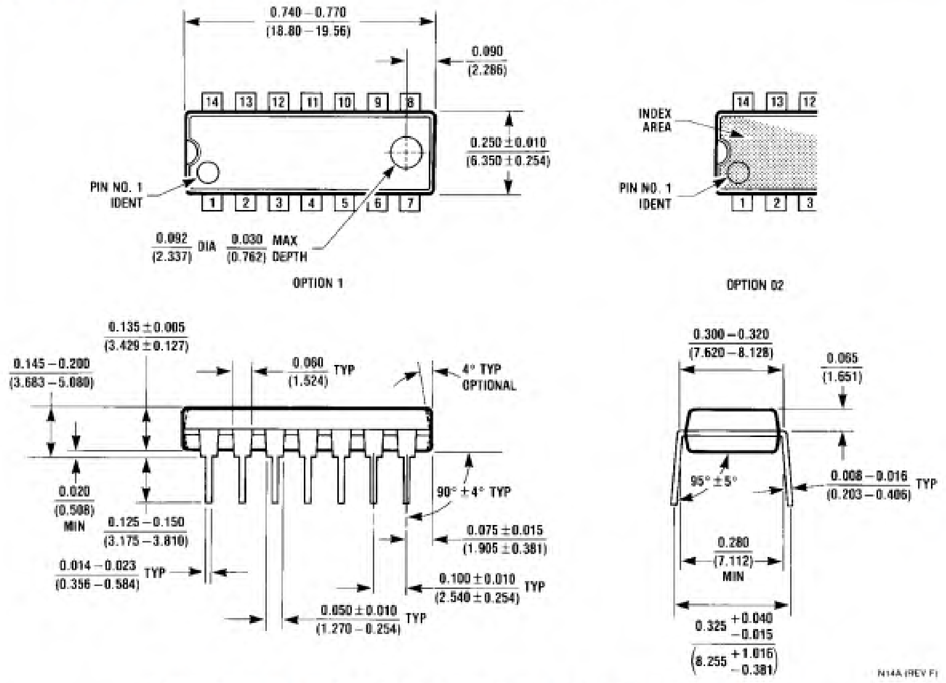
Symbol	Parameter	From (Input) To (Output)	$R_L = 400\Omega$, $C_L = 15$ pF		Units
			Min	Max	
f_{MAX}	Maximum Clock Frequency		15		MHz
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	Clear to Q		40	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	Clear to $\overline{Q}$		25	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	Clock to Q or $\overline{Q}$		40	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	Clock to Q or $\overline{Q}$		25	ns

www.fairchildsemi.com 2

Figure 52: IC 7473 Dual JK Flip-Flip Datasheet Screenshot 2

DM7473 Dual Master-Slave J-K Flip-Flops with Clear and Complementary Outputs

Physical Dimensions inches (millimeters) unless otherwise noted



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N14A

Fairchild does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and Fairchild reserves the right at any time without notice to change said circuitry and specifications.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

www.fairchildsemi.com

3 www.fairchildsemi.com

Figure 53: IC 7473 Dual JK Flip-Flip Datasheet Screenshot 3

- IC 7408 quad 2-input AND gate datasheet:

FAIRCHILD
SEMICONDUCTOR TM

August 1986
Revised February 2000

DM7408 Quad 2-Input AND Gates

DM7408
Quad 2-Input AND Gates

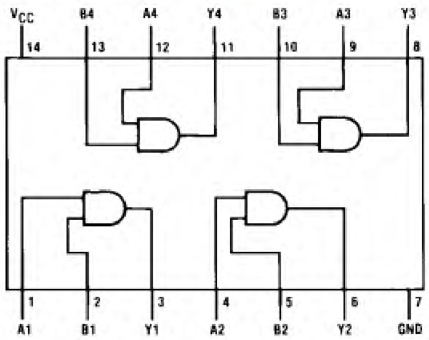
General Description

This device contains four independent gates each of which performs the logic AND function.

Ordering Code:

Order Number	Package Number	Package Description
DM7408N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Connection Diagram



Function Table

Y = AB

Inputs		Output
A	B	Y
L	L	L
L	H	L
H	L	L
H	H	H

H = HIGH Logic Level
L = LOW Logic Level

 DS006498 www.fairchildsemi.com

Figure 54: IC 7408 AND Gate Datasheet Screenshot 1

DM7408

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	5.5V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.8	mA
I_{OL}	LOW Level Output Current			16	mA
T_A	Free Air Operating Temperature	0		70	°C

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −12 mA			−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max V_{IL} = Max	2.4	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IH} = Min		0.2	0.4	V
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 5.5V			1	mA
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.4V			40	µA
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V			−1.6	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−18		−55	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		11	21	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		20	33	mA

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time.

Switching Characteristics

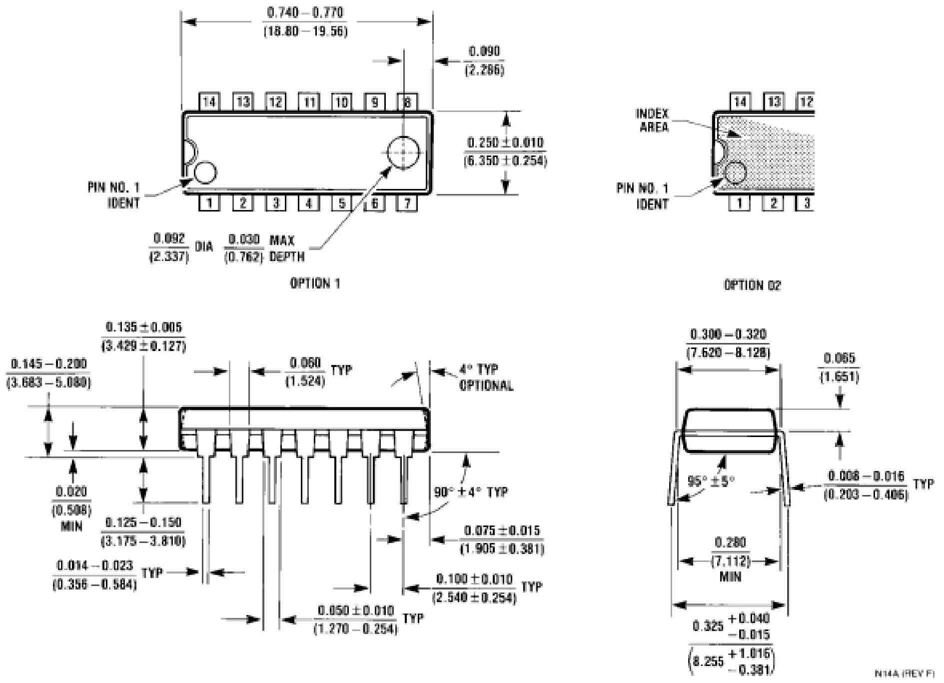
at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	Conditions	Min	Max	Units
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	C_L = 15 pF R_L = 400Ω		27	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output			19	ns

www.fairchildsemi.com 2

Figure 55: IC 7408 AND Gate Datasheet Screenshot 2

Physical Dimensions inches (millimeters) unless otherwise noted



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N14A

Figure 56: IC 7408 AND Gate Datasheet Screenshot 3

- L298N motor driver datasheet:

HT Handson Technology

User Guide

L298N Dual H-Bridge Motor Driver

This dual bidirectional motor driver, is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow you to easily and independently control two motors of up to 2A each in both directions.It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board equipped with power LED indicators, on-board +5V regulator and protection diodes.

SKU: MDU-1049

Brief Data:

- Input Voltage: 3.2V~40Vdc.
- Driver: L298N Dual H Bridge DC Motor Driver
- Power Supply: DC 5 V - 35 V
- Peak current: 2 Amp
- Operating current range: 0 ~ 36mA
- Control signal input voltage range :
- Low: -0.3V ≤ Vin ≤ 1.5V.
- High: 2.3V ≤ Vin ≤ Vss.
- Enable signal input voltage range :
  - Low: -0.3 ≤ Vin ≤ 1.5V (control signal is invalid).
  - High: 2.3V ≤ Vin ≤ Vss (control signal active).
- Maximum power consumption: 20W (when the temperature T = 75 ℃).
- Storage temperature: -25 ℃ ~ +130 ℃.
- On-board +5V regulated Output supply (supply to controller board i.e. Arduino).
- Size: 3.4cm x 4.3cm x 2.7cm

1 www.handsontec.com

Figure 57: L298N Datasheet Screenshot 1

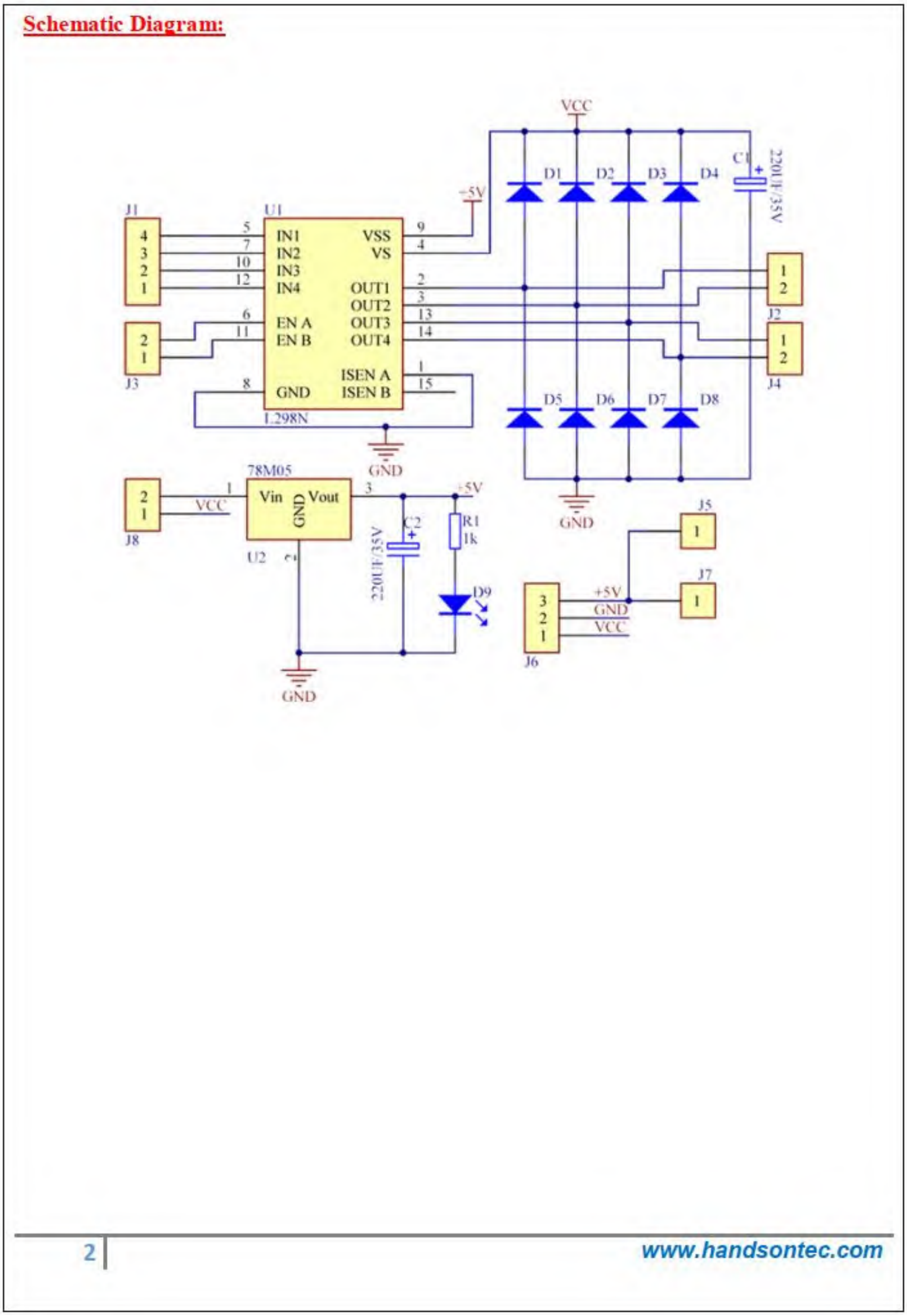


Figure 58: L298N Datasheet Screenshot 2

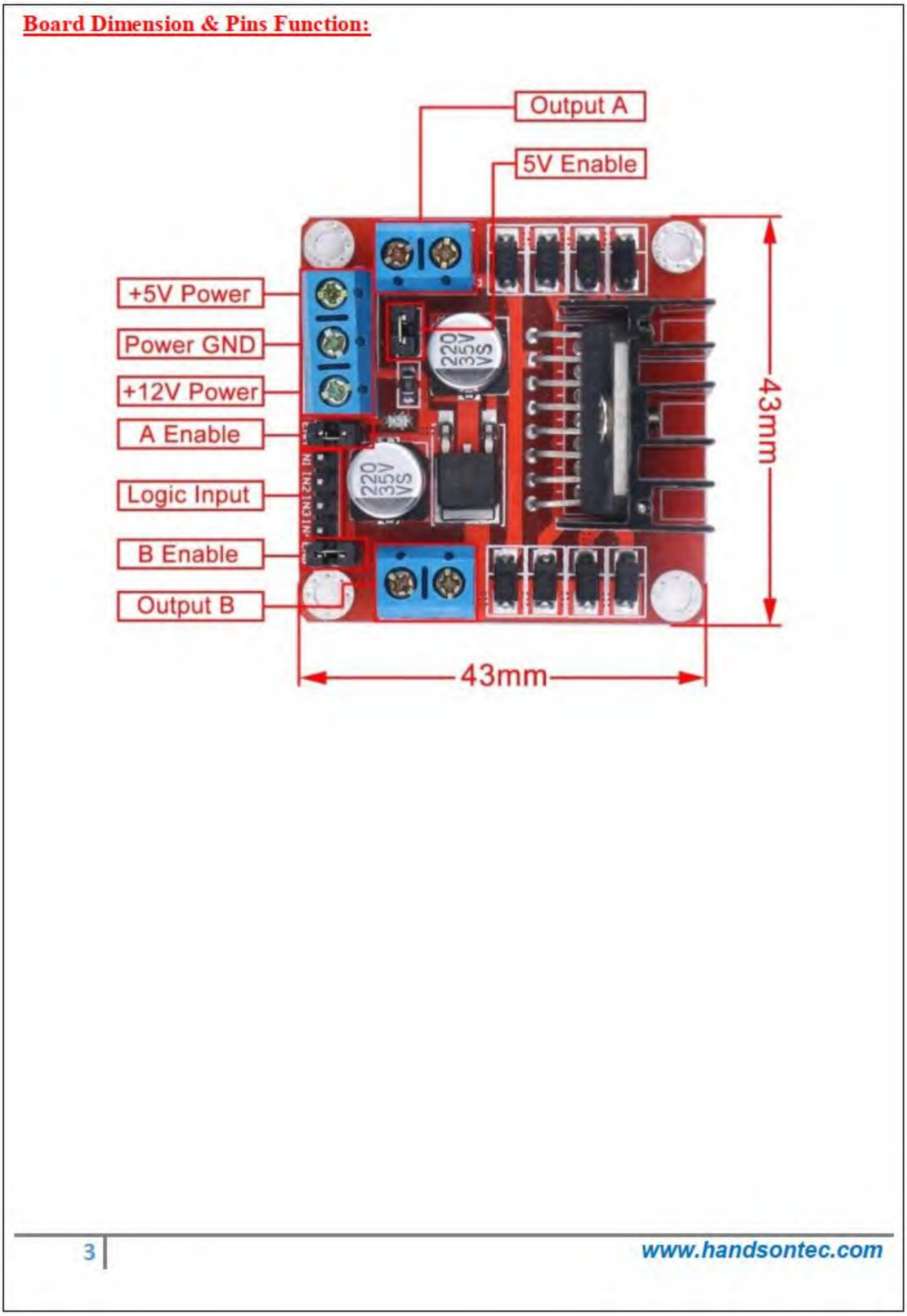


Figure 59: L298N Datasheet Screenshot 3

VII. References:

- M. Hamad, J. Mounsef (2006), Electronic Circuit Laboratory Manual, first edition, NDU press
- Adel S. Sedra, Kenneth C. Smith (2011), Microelectronic Circuits International Sixth Edition, Oxford University Press
- 1N4007 diode datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/58822/DIODES/1N4004.html
- TSAL6100 IR transmitter diode datasheet: https://www.vishay.com/docs/81009/tsal6100.pdf
- BPV10NF IR receiver diode datasheet: https://www.vishay.com/docs/81503/bpv10nf.pdf
- 2N2222A NPN BJT datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/235073/ETC2/2N2222A.html
- LM339 quad comparator datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/542763/LUGUANG/LM339.html
- SRD-12VDC-SL-C relay Datasheet: https://www.alldatasheet.com/datasheet-pdf/pdf/1131793/SONGLERELAY/SRD-12VDC-SL-C.html
- 555 timer datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/100919/HARRIS/LM555.html
- SG90 micro servomotor datasheet: http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf
- IC 7473 dual JK flip-flop datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/50911/FAIRCHILD/7473.html
- IC 7408 quad 2-input AND gate datasheet: https://pdf1.alldatasheet.com/datasheet-pdf/view/50893/FAIRCHILD/7408.html
- L298N motor driver datasheet: https://components101.com/sites/default/files/component_datasheet/L298N-Motor-Driver-Datasheet.pdf