Functions of the Components of the IR Add-on Module

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This exercise is designed to help you understand the function of each component of the IR Add-on module. Read the descriptions starting below. Then complete the matching exercise on page four.

The module schematic (on page 8) is divided into five circuits. The voltage regulator (VR) of the **Power Supply Circuit** provides five volts regulated power to IC1, IC2 and IC3. Direct supply of power from the nine volt battery to IC1 and IC2 is not possible because their maximum voltages allowed are 6.0 and 5.5 volts respectively.

Integrated circuit IC1 is a **Hex Schmitt-Trigger Inverter** (manufactured by Texas Instruments, part number SN74AC14). The word Hex indicates that the chip contains six independent inverters, as can be seen in the schematic. An inverter converts a low voltage input to a high voltage output and a high voltage input to a low voltage output. The input pins are 1, 3, 5, 9, 11, and 13 and the output pins paired with the inputs are pins 2, 4, 6, 8, 10 and 12 respectively. Positive power is applied at pin 14 and negative power at pin 7. The IR module utilizes only four of the six inverters.

The two inverters connected to pins 1 through 4 are utilized in the **IR Emitter Circuit**. IR emitter D5 (a type of LED that emits infrared light) must emit infrared light at a pulse rate of 38,000 Hz. That means the IR emitter must turn on and off 38,000 times each second.

The current pulses that turn the IR emitter on and off are produced by the inverter connected to pins 1 and 2. At the instant power is applied to IC1, pin 2 outputs 5 volts, which causes current to flow through resistors R9 and R8. The resistance of R8 is adjustable so that the rate of current flow can be adjusted. As the current flows through the resistors, it charges capacitor C6 (as a capacitor charges, it stores electrons). As the capacitor is charged, the voltage applied to pin 1 (input pin) rises because the voltage is rising in the capacitor. At a certain rising voltage on pin 1, the inverter is triggered which causes pin 2 to output 0 volts. When this happens, C6 begins to discharge (electrons drain out of the capacitor). As the voltage supplied to pin 1 by C6 drops, at a certain low voltage, the inverter is triggered once again and the output voltage at pin 2 changes back to 5 volts. This cycle repeats over and over continuously as long as power is applied to IC1. The time period of the cycle is determined by the values of resistors R8 and R9 and the value of capacitor C6. The higher the value of C6, the longer time it takes for the capacitor to charge and discharge. The higher the value of resistors R8 and R9, the lower the current flow, which results in a longer time to charge and discharge capacitor C6.

The values of C6, R8 and R9 were selected so that the capacitor will charge and discharge about 38,000 times each second. As you have already learned, the marked value on resistors is usually not the exact true value. The true value must be determined by a meter. The same applies for capacitors. Therefore, it is necessary to have some way to adjust those values so that the charge/discharge rate equals 38,000 Hz. That is why R8 is an adjustable resistor.

Output pin 2 of IC1 is also connected to input pin 3 of IC1. Therefore, when the output of pin 2 is high (5 volts) the output of pin 4 is low (0 volts). And when the output of pin 2 is low, the output of pin 4 is high. The output of pin 4 is the opposite of the output at pin 2. Also, the output pulse at pin 4 will be 38 kHz if that is the rate at output pin 2.

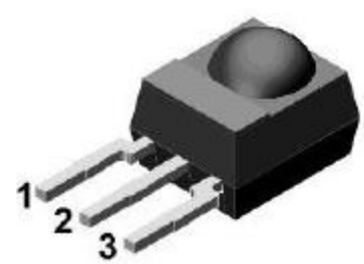
Pin 4 of IC1 is connected to a series circuit containing resistors R10 and R11 and IR LED (IR emitter) D5. Therefore, if the inverter output of pin 4 cycles at 38 kHz, then the IR LED D5 will flash on and off 38,000 times each second. That is exactly what we want to happen because the IR detector (IC2) is designed to detect IR light at a pulse rate of 38 kHz. Resistors R10 and R11 limit the amount of current supplied to D5. R11 is an adjustable resistor, which is used to adjust the brightness of the IR LED D5.

You may be wondering why it is necessary to use two inverters to supply a 38 kHz pulse current to the IR emitter. Why not just connect the output pin 2 to the circuit containing D5? If we did that, the pulse rate would not be stable. The circuit containing D5 would share the current supplied by pin 2 with the circuit containing R8, R9 and C6. During operation, D5 heats, causing a variation in the current draw of the D5 circuit. That variation would also cause a variation in the pulse rate output at pin 2. To prevent instability in pulse rate, the output of pin 2 is connected to the input at pin 3. By this method, the current supplied to R8, R9 and C6 is constant and the pulse rate produced is stable.

The IR module must produce and detect infrared light pulsing at 38 kHz. Now let's learn how the IR pulse is detected. Integrated chip IC2 is an IR Receiver Module (manufactured by Vishay, part number TSSP4038). This IC is designed to detect infrared light pulsing at a rate of 38 kHz. That is why the IR emitter D5 is adjusted to pulse at 38 kHz.

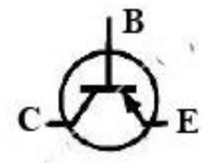
IC2 is most sensitive to infrared light at a wavelength of 950 nanometers (nm). Its sensitivity to light at 850 and 1100 nm is only 10% of that at 950 nm. IC2 is not sensitive at all to visible light. Therefore, we want to use an IR emitting diode that emits light close to a wavelength of 950 nm. The IR LED D5 selected for this project is a Vishay part number CQY36N, which emits IR at a peak of 950 nm, a good match to our IR detector.

IC2 has three pins. The middle pin (pin 2) connects to the negative power supply. Pin three connects to the positive power supply, which must not be more than 5.5 volts. Ceramic capacitor C3 is connected between pins 2 and 3 to function as a noise filter for IC2 (it stabilizes the voltage supply). Pin 1 is the output pin of IC2. If no IR pulses at 38 kHz are detected, then pin 1 outputs 5 volts. If IR pulses are detected, then pin 1 outputs 0 volts. Notice that pin 1 of IC2 is connected to pin 13 of IC1. Therefore, pin 13 of IC1 receives the output of IC2.



When IR pulses of 38 kHz are detected, we want our IR module to disconnect power from the robot motors. Let's follow the path of action that makes that happen. When IC2 detects the IR pulse, it supplies 0 volts to input pin 13 of IC1. The 0 volt input at pin 13 causes the output of the inverter at pin 12 to be 5 volts. Pin 12 is connected to input pin 11 of another inverter. Therefore, the output pin 10 of that inverter outputs 0 volts when 5 volts is applied to input pin 11. To summarize, an input of 0 volts at pin 13 results in an output of 0 volts at pin 10. The output of pin 10 is connected to pins 2 and 6 of IC3. IC3 is an LM393 dual voltage comparator, the same type used on the main PCB of the robot. Therefore, the output of pin 10 of IC1 is connected to the negative input pins of the LM393. Recall that if the input voltage of the negative input pin is greater than the input voltage at the positive input pin, the internal switch of the voltage comparator is turned on. If IC2 detects the IR pulses, 0 volts is applied to pins 2 and 6 of LM393 (IC3). The voltage divider created by resistors R2 and R3 supplies 2.5 volts to pins 3 and 5 of IC3, which are the positive input pins for the two voltage comparators. Therefore, if IR pulses are detected, the switches of IC3 are turned off, which in turn turns off power transistors Q1 and Q2. When transistors Q1 and Q2 are turned off, power is disconnected. That is exactly what we want. When IR pulses at 38 kHz are detected, we want the IR module to disconnect power to the motors so that the robot will stop.

The function of IC3 in this module is essentially the same as the LM393 chip used on the main robot PCB. It is wired to control power to the motors. Outputs at pins 1 and 7 are connected by resistors R5 and R4 to the bases of transistors Q2 and Q1, which in turn provide power to the robot motors.



The transistors Q1 and Q2 are the PNP type and the symbol for them is at the right. These transistors have three wires which connect to the three parts of the transistor: the emitter (E), the collector (C) and the Base (B). A small amount of current flowing through the base wire will allow a much larger amount of current to flow from the emitter to the collector. You should notice that the base of each transistor is connected to one of the outputs of IC3. Between the base and the IC, there is a resistor to control the amount of current that can flow through the base. When the voltage comparator switch of IC3 is on, then the base of the transistor is connected to the negative side of the power supply (through its current limiting resistor, then the output pin of IC3, which connects to pin 4 [negative power] of IC3). When the base connects to negative power, then current flows through the base, which in turn allows current to flow from the emitter to the collector.

Why don't we just connect the motors directly to IC3 and eliminate the transistors? IC3 cannot handle the amount of current required to run the motors. If we connected the motors directly to IC3, it would burn out quickly. Instead, we use a small amount of current flowing through IC3 to control a much larger current flowing through the power transistor.

There is one circuit remaining that we have not discussed yet. Red LED D6 is connected to output pin 12 of IC1. When IR pulses are detected, pin 12 outputs 5 volts, which causes D6 to glow indicating detection. The red color of the LED reminds us that the robot is in the stop condition. Resistor 12 functions as the current limiter for D6.

Fill in the blank for each component with the correct letter, using the list starting on the next page

C1 _______

C2 _______

C3 _______

C4 _______

C5 _______

C6 _______

C7 _______

R2 _______

R3 _______

R4 _______

R5 _______

R8 _______

R9 _______

R10 _______

R11 _______

R12 _______

D1 _______

D5 _______

D6 _______

Q1 _______

Q2 _______

IC1 _______

IC2 _______

IC3 _______

VR _______

Matching Answers (you may use an answer more than once)

A. Controls the amount of current supplied to the base of transistor Q2

B. Fixed resistor used to control the charging rate of C6.

C. Stabilizes voltage supplied to IC3

D. Stabilizes voltage supplied to IC2

E. Hex Schmitt-Trigger Inverter, an integrated circuit that contains six inverters. An inverter is used to invert an input. As an example, the first inverter of this IC has its input at pin 1 and its output at pin 2. If 0 volts are applied to pin 1, then 5 volts are output to pin 2. If 5 volts are applied to pin 1, then 0 volts are output at pin 2.

F. Red LED that glows when IC2 detects pulses of IR light at 38 kHz. This LED indicates when the robot is in the stop condition due to a detection of pulsing IR light.

G. One of two resistors in series that divide the 5 volt regulated supply and provides 2.5 volts to pins 3 and 5 of IC3

H. Stabilizes voltage supplied to IC1

I. IR Receiver Module – designed to detect pulsing IR light at a rate of 38 kHz. If the pulsing IR light is detected the IC outputs 0 volts. If the pulsing IR light is not detected, the IC outputs 5 volts. The output of this IC is connected to input pin 13 of IC1.

J. Stabilizes voltage on the output side of the voltage regulator

K. Stabilizes voltage on input side of the voltage regulator

L. Diode used as a safety measure, to insure that a reversed polarity connection of power to the board will not damage the components (in other words, the diode prevents current to flow in board circuits if the battery is connected with the wrong polarity)

M. Dual voltage comparator, contains two voltage comparators. Each voltage comparator has two inputs and one output. If the voltage applied to the negative (-) input is greater than the voltage supplied to the positive (+) input, then the output of the comparator is connected to the negative side of the power bus (in other words, the output pin is connected to pin 4). Thus, the comparator acts like a switch.

N. Adjustable resistor used to control the charging rate of C6. This resistor is part of the 38 kHz oscillator. This resistor is used to adjust the oscillation rate to 38 kHz.

O. Controls the amount of current supplied to the base of transistor Q1

P. PNP bipolar transistor that controls power to the robot motor connected to the right wheel.

Q. Adjustable resistor used to control the amount of current supplied to the IR emitting diode D5. This resistor is used to adjust the brightness of the IR emitting diode.

R. Capacitor that is part of the oscillator, which oscillates at 38 kHz. The capacitance of this capacitor is sized so that it will charge and discharge at a rate of 38 kHz

S. Fixed resistor used to control the amount of current supplied to LED D6

T. IR emitting diode that flashes at a rate of 38 kHz

U. Fixed resistor used to control the current supplied to IR emitting diode

V. PNP bipolar transistor that controls power to the robot motor connected to the left wheel

W. Voltage Regulator – input voltage from battery is approximately 9 volts and output of this integrated circuit is 5 volts. Some of the ICs for this project would not operate properly if supplied with 9 volts, which is why this regulator is used to reduce the voltage.

Answer Key – give to members only after they have completed the exercise

C1 ___K___

C2 ___J___

C3 ___D___

C4 ___H___

C5 ___H___

C6 ___R___

C7 ___C___

R2 ___G___

R3 ___G___

R4 ___O___

R5 ___A___

R8 ___N___

R9 ___B___

R10 ___U___

R11 ___Q___

R12 ___S___

D1 ___L___

D5 ___T___

D6 ___F___

Q1 ___V___

Q2 ___P___

IC1 ___E___

IC2 ___I___

IC3 ___M___

VR ___W___

IR add-on module circuit board assembly - Jeffrey La Favre – January 27, 2015