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Development, Design, Analysis and Construction of a Digital Electronic Jack

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ABSTRACT

Car jack is one of the important tools that must always be in the car. This is to salvage unforeseen situations which may be as a result of flat car tyres or need to examine car underneath for either changes, examination or repairs. However, jacking a car up using manual / screw jacks requires enough energy and technicalities to achieve. These challenges thereby prompted us (the authors) towards writing this paper on design and construction of a remote control motor jack using an Infra-red automated transmission. The system was designed with dc motors actuators to control the hydraulic jack up and down using an infra-red transmitter signals which are modulated beam capable of transmitting two coded frequencies. The receiver circuit would be able to receive the transmitted infra-red beam and be able to process and decode the two control signals for the jack movement and direction. The control mechanism consisting of the dc motor and the link mechanism are arranged in such a way that it will allow smooth control of the fabricated hydraulic jack capable of lifting loads placed on it. The control program / code for the circuit is written in Assembly language using MPASM compiler which then downloaded the code to the PIC16F84A microcontroller.

Keywords: *Car; Infra-red; Jack; Microcontroller*

INTRODUCTION

Car jack is a mechanical device being used for lifting car to allow drivers and mechanics get underneath the car, usually to change a tyres, oil filters or perform some form of mechanical maintenance. Most car jack that come with cars are of the screw type mechanisms. Car jack is a very important device that vehicle owners must have to help in servicing their cars when the need arises. The need for the car jack is often necessitated by flat tires that the needs for repair or replacement mostly requiring going under the vehicle before accessing such areas. Most people are used to the manual jack when it comes to car repairs and servicing.

However, there are two kinds of jacks: screw and hydraulic jacks. There also exists scissors jacks and Bumper jacks (also categorized under the screw jacks) which are very common in recent and old cars respectively. The type of the car jack used will determine the amount of physical effort required to operate and to raise the car to the desired height which could be energy sapping (especially in large tonnage vehicles) at most times. Therefore the main purpose of this research is to design and effortless car jack with automatic control using controller actuator from a push button point.

REVIEW OF CAR JACK

Car jack is placed on a flat concrete surface and one must ensure no one is sitting in the car as preventive measures during usage. The car descends by reversing the process: turn the screw counterclockwise, making sure to tighten the lug nuts after the car's tire has minimal weight on the ground surface, and then lowering the jack back in anticlockwise manner. The jack is made out of various types of metal, but the screw itself is generally made out of lead.

The Screw Jack

This has a thread designed to withstand an enormous amount of pressure. This is due to the fact that it is generally holding up heavy objects for an extended amount of time. Once up, they normally self-lock so that they won't fall if the operator lets go, and they hold up well to the wear of repeated use. If they are made with a ball nut, they will last longer because there is less friction created with this type of jack. However, they will not self-lock. This type of Jack could be very dangerous if not carefully handled [6].

In terms of operation of a screw jack, the jack can be raised and lowered with a metal bar that is inserted into the jack (Fig. 1). The operator turns the bar with his hands in a clockwise direction. This turns the screw inside the jack and makes it go up. The screw lifts the small metal cylinder and platform that are above it. As the jack goes up, whatever is placed above it will raise as well, once the jack makes contact. The bar is turned until the jack is raised to the level needed. To lower the jack the bar is turned in the opposite direction. However, scissors jacks are the most favorite type of car jacks, so in most cases, they provide it with their cars. This type of jacks utilizes the central screw mechanism for raising and lowering a car.

Figure 1. Screw Jack

An Hydraulic Jack

The hydraulic jack is common in car shops and garages. It uses hydraulic fluid to push the jack head up and lift the car. The hydraulic fluid is pumped into the jack head which extends the arm of the jack either by turning a crank that raises the bar or by pushing up the bar itself (Fig. 2). It can be a wheeled or non-wheeled model.

Figure 2. Pump Jack

Other types of jacks include lifts operated by foot pedals. When you press the foot pedal, a small crank turns and slowly lifts the jack. It ratchets into place on every step, and then the operator can reset and depress the jack pedal again to lift the car another few inches (Fig. 3).

Figure 3.Large Floor Jack

PROPOSED REMOTE CONTROL CAR JACK

The operational principle of the remote control car jack is represented in the block diagram shown below (Fig. 4). This shows the basic building block of the control system.

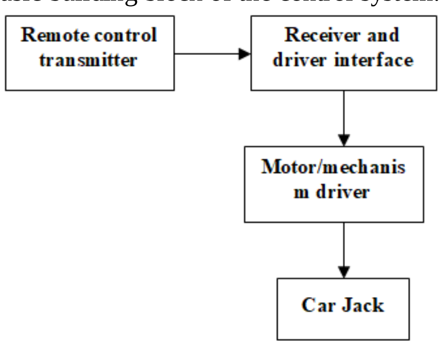


Figure 4. Block diagram of the remote control car jack

Remote Control Transmitter

This is the transmitter stage of the system whose function is to transmit two frequency coded signals to the receiver stage to control eventual movement of the jack for up and down movement. It consists of an oscillator circuit that generates two different frequencies, one to control up movement and the other for down movement control. However, the control communication means is the infra-red link.

Receiver and Driver Interface

This stage consists of the infra-red receiver stage that picks up the transmitted infra-red beam and convert it to electrical signals, simplifies and shapes the signal to pulses and then decode the frequencies to switch power for jack direction control; up or down. This stage also consists of the jack mechanism motor driver interface that helps connect the control circuit to the jack mechanism.

Jack Control Motor Mechanism

This stage consists of the mechanism that controls the car jack. This mechanism consists of the dc motor and the gear and link mechanism for transmission of movement from the motor to the jack. This link mechanism function is to convert the rotary movement to linear movement.

Car Jack

The car jack of choice is the hydraulic car jack because it is the type that requires less force for its operation. The individual stage operational circuit would be determined that will help to achieve the objectives of these stages and the goal of the project. The design will also involve design calculations and relevant analysis for component determination also as required.

DESIGN SPECIFICATION

The design of the push button control car jack consists of the following stages;

- Power Supply stage
- Infra-red transmitter stage
- Infra-red receiver stage
- Microcontroller stage
- Jack mechanism driver

Power Supply

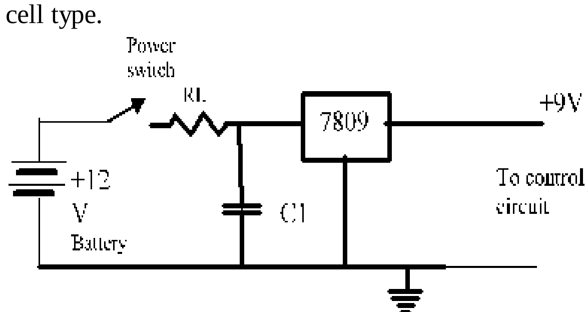
The circuit needs a power supply of +9V for the control circuit. The power source of the circuit is from the car battery which 12V dc. Fig. 5 shows the power supply diagram. R_L is a limiting resistance for the regulator. The circuit will need up to 300mA for its operation from the voltage regulator.

Capacitor C1 is connected for decoupling of noise signals [2] and its chosen value is 0.1µF. To obtain the regulated +9V a voltage regulator of 7809 was used in the design to get the voltage. The specification is as shown.

7809 Voltage Regulator;

Maximum input voltage = 35V
Output voltage = 9V
Drop out voltage = 2V
Minimum input voltage = 11V
Output current = 1A
For Supply voltage Vcc = 12V
Regulator voltage = 9V
Load current Ia = 0.3A
$R_L = (Vcc - Vreg) / Ia = (12 - 9) / 0.3 = 10\Omega$

The transmitter circuit was powered by a 9V battery dry cell type.



Infra-Red Transmitter

The circuit consists of two 555 timer astable multivibrator and an infra-red LED driver serving as the transmitter. One astable multivibrator (IC_2) function is to generate pulses with a frequency of 38 kHz. This choice of 38 kHz is based on the infra-red receiver module that operates on a 38 kHz carrier. The second mutivibrator (IC_1) is used to generate two low frequency pulses; one to control the upward movement of the jack and the other frequency to control the down movement. The modulated infra-red beam is directed towards the direction of the infra-red receiver of the car jack mechanism. The circuit is of the astable multivibrator (IC_1) for the low frequencies are presented in Fig. 6.

The expression for frequency of oscillation is

$$F = 1.44 / (R_A + 2R_B)\, C_1 \quad \text{--------------------(1)}$$

Choosing $R_B = R_3 = 10k\Omega$

$C_1 = 1\mu f$

$F1 = 68$ Hz

$R_A = R_1 = ((1.44 / (F\, C_1)) - 2R_B)$

$= ((1.44 / (68 \times 1 \times 10^{-6})) - 20000)$

$R_A = R_1 = 1176\ \Omega$

A resistor value of 1.2kΩ was chosen as the closest value.

Then for F2 = 48 Hz

$R_B = ((1.44 / (F\, C_1)) - 2R_B)$

$= ((1.44 / (48 \times 1 \times 10^{-6})) - 20000)$

$R_2 = 10000\ \Omega = 10\ k\Omega$

Equation1 applies to the carrier frequency generation using IC2. thus;

Choosing $R_B = R_5 = 18k\Omega$

$C_1 = 1nf$

$F = 38$ kHz

$R_A = R_4 = ((1.44 / (F\, C_1)) - 2R_B)$

$= ((1.44 / (38\,000 \times 1 \times 10^{-9})) - 36\,000)$

$R_A = R_4 \approx 1.8\ k\Omega$

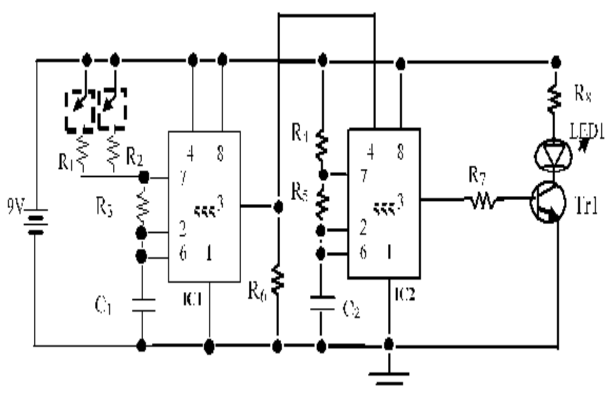


Figure 6. Infra-red Transmitter circuit

Infra-Red Receiver

The infra-red receiver circuit adopted for this circuit was borne out of the need for reliability. This was implemented using infra-red receiver module specially designed for infra-red reception of 38 kHz signals. It consists of the infra-red receiver photo-diode, filter and amplification circuits and demodulator inbuilt inside it and the diagram is in Fig. 7.

The second infra-red circuit uses the infra-red receiver module IRX-TSOP1738 model for the infra-red detector circuit. The TSOP17xx – series are miniaturized receivers for infrared remote control systems. PIN diode and preamplifier are assembled on lead frame, the epoxy package is designed as IR filter [10]. The demodulated output signal can directly be decoded by a microprocessor. TSOP17xx is the standard IR remote control receiver series, supporting all major transmission codes. It has the following features;

- Photo detector and preamplifier in one package
- Internal filter for PCM frequency
- Improved shielding against electrical field disturbance
- TTL and CMOS compatibility
- Output active low
- Low power consumption
- High immunity against ambient light
- Continuous data transmission possible (up to 2400 bps)

Operating frequency is 38 kHz and supply voltage of 5V. This implies that the module was used for 38 kHz signal detection to control the jack mechanism.

Resistor R9 is for current limiting as specified in the datasheet and the specified value;

R9 = 100Ω

Transistor Tr2 amplifies the signal from the infra-red receiver module.

Collector current $Ic = \beta Ib = 1.2mA$

$Ib = Ic / \beta$

Ib = 1.2 x 10-3 / 100 = 1.2 x 10-5 A

R11 = (Vcc – Vce) / Ic = (5 - 0.2) / 1.2 x 10-3 = 4000 Ω ≈ 3.9k Ω

R10 = (Vcc – VIR – Vbe) / 1.2 x 10-5

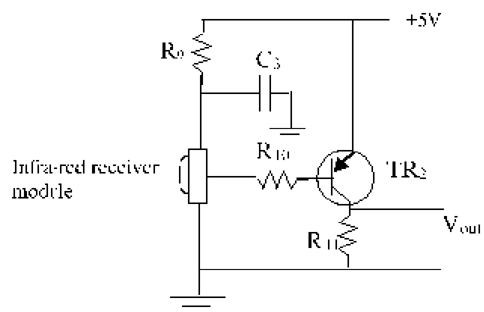
Where VIR is the output from the infra-red receiver module;

VIR = 3V

R10= (5 – 3- 0.7) / 1.2 x 10-5 ≈ 10k Ω

Capacitor C3 was added to reduce noise signals across the infra-red receiver module, and its chosen value is 10μF (specified).

Tr2 is a PNP, 2SA733 transistor, with following data;



Actuator / Motor Drive Circuit

The motor or actuator control circuit is made up of the transistor-relay switches for controlling power to the d.c motor that moves the car jack. A transistor relay switch will control power to move it in forward direction while the other will be for the reverse direction (Fig. 8).

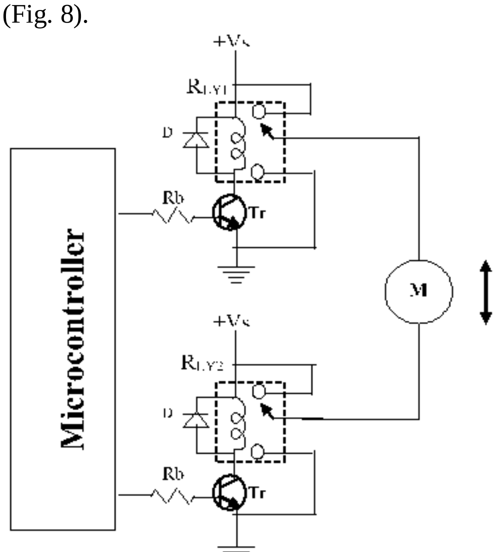


Figure 8. DC motor-actuator drive circuit

Relay specs:

Relay resistance = 400Ω

Relay operating Voltage = 12V

Operating Current Ic = V / R = 12 / 400

I_C = 30mA

The transistor is the C945 NPN type.

Microcontroller Circuit

The microcontroller used in this work is the Microchip PIC16F84A (Fig. 9). It has Only 35 single word instructions to learn and all instructions single-cycle except for program branches which are two-cycle [1]. The features of the microcontroller are as listed below.

- Operating speed: DC - 20 MHz clock input
- 1024 words of program memory [9]
- 68 bytes of Data RAM, 64 bytes of Data EEPROM
- 14-bit wide instruction words, 8-bit wide data bytes
- Direct, indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin,
  - TMR0 timer overflow
  - PORTB<7:4> interrupt-on-change
  - Data EEPROM write complete

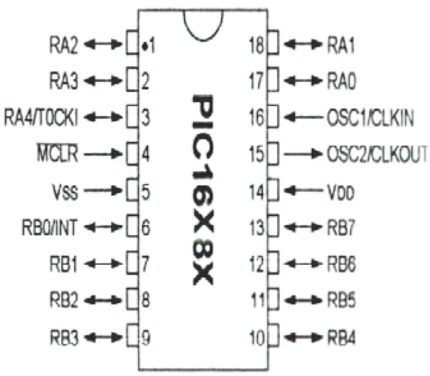
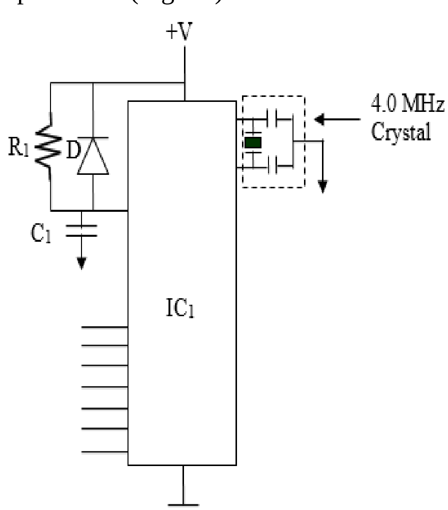


Figure 9. Pin layout of the PIC16F84A Microcontroller

Pin 15 and pin 16 are for oscillator. The oscillator of choice because of its stability is the crystal oscillator and the chosen one is the 4.0 MHz because of its availability. Pin 4 is the master clear terminal and it is used here for start-up delay to protect the program from timing problem at start caused by power up surge [9]. Resistor R and Capacitance C, determine the delay time. Diode D discharges the capacitor C fast during shutdown or power-off (Fig. 10).



For a start-up time delay Ts = 330µs and C_1 = 100nF, thus

$R_1 = Ts / 0.7Cs = 330 \times 10^{-6} / 0.7 \times 100 \times 10^{-9}$

$R_1 = 4.7\ k\Omega$

OPERATIONAL PRINCIPLE OF THE REMOTE CONTROL CAR JACK

The operational design and analysis of the remote control car jack is hereby shown in a Circuitry representation (Fig. 11) for system construction.

IC_1 is a 555 timer astable multivibrator and its function is to generate two low frequency pulses of 68Hz and 48Hz to drive IC_2. R_6, R_7, R_8 and C_3 determine the frequency of oscillation of IC_1.

IC_2 is also a 555 timer astable multivibrator. Its function is to generate 38KHz pulse for driving the infra-red LED.

Transistor TR_1 is a current amplifier for driving/boosing the output of IC_2 to drive the LED. R_9, R_{10}, C_4 determine the 38KHz value for IC_2.

The infra-red beam is directed towards the receiver unit. The infr-red module receives the signal and demodulates it to give an output which is sent to the microcontroller. TR_2 amplifies the output of I_R module. The microcontroller, whenever it receives the pulses, checks for the frequency and if it is 68Hz, it enable the motor to control the jack for upward movement by sending a pulse o TR_3. TR_3 in turn conducts and activate RLY_1 and if it should be 48Hz it will send a pulse to TR_4 for downward movement control of the jack.

Diodes D_1 and D_2 protects TR_3 and TR_4 from relay switching surge currents. M is the motor to control the jack (d.c motor).

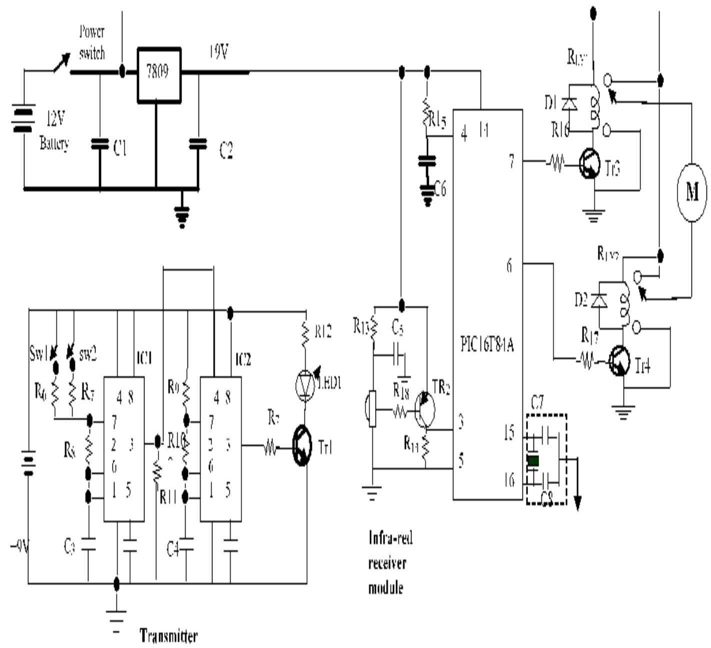


Figure 11. Complete Circuit Diagram of Remote Control Motor Jack

SYSTEM CONSTRUCTION

After designing the circuit and determining components to be used with their various values, the construction was embarked on for both the control circuit and the mechanisms interoperability. It involves mounting of the components on a project-board (Breadboard) with the components arrangement which started with the power supply comprises of the limiting resistor and the voltage regulator since the other stages would need power for testing. An assembly language [13] code was developed for the microcontroller (wired together with jumper wires to activate the circuit) to control the circuit and to monitor / decode the output of the infrared sensor in controlling the jack.

The next construction phase is the infra-red receiver stage followed by the motor-drive control stage connected with the relays for power control and mechanisms regulation. The transmitter circuit was set up on a different project board. The transmitter consists of the 555 timer and resistors and capacitors and infra-red LED. A 9V battery was used to power the transmitter circuit. The circuit was tested after the whole circuit components have been connected as indicated by the design and circuit schematics (Fig. 11*)*, stage by stage to ensure they are working well. After the test, the components were transferred to Vero board for permanent soldering. The soldering too was done stage by stage to ensure proper connection of parts and wiring. I.C sockets were used for the I.Cs for protection of the I.Cs from soldering iron heat. Thereafter, the complete construction work was tested and the complete circuit was placed in motor- drive mechanism housing made of wood.

Finally for the Hydraulic Jack construction, the jack was mounted on a metal sheet and welded to it. The metal sheet measures 1-foot sq. the dc motors were welded with metal support to the point of control. The next test was to check the infra-red remote control with the receiver to see if the circuit would respond. The infra-red receiver output was measured to see if there are pulses followed by the response of the microcontroller from the drive to the relays.

RESULTS

The results of the test mainly presented are for the expected response of transmitter, receiver and the microcontroller response with the jack movement whenever the transmitter is pressed on and off. The result is presented below (TABLE I).

Table I. Test Results of the infra-red remote motor jack

S/No	IR Transmitter	Microcontroller response	Hydraulic jack response
1.	Up Key press#1	Increase in voltage	Moves up
2.	Down Key press#2	Decrease in voltage	Moves Down

CONCLUSION

As of when the research was carried out, no existing work has been done on local remote controlled car jack; thereby making the system stands a better chance for commercial production with little improvements in this regard. However, the Maximum allowable load capacity is three tons as the jack is five tons and the maximum height of lift is seven inches (18 cm) due to jack size. Meanwhile, the Maximum distance between the jack and the remote controller is five feet (153cm) for effective operation. This remote control car jack was designed with dc motors actuators to control the hydraulic jack up and down as controlled by an infra-red transmitter. The transmitter has two controls for upward control and the other for bringing down the jack. The infra-red transmitter transmits a modulated infra-red beam towards the receiver. The receiver on reception of the weak signals, amplify and demodulate the signals and then the microcontroller interprets the signal to know the direction to control the jack. However, tremendous efforts were successfully made in this research to reduce the systems sensitivity especially to ambient light which is a typical problem with infra-red control systems.

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