DESIGN AND CONSTRUCTION OF A MICROCONTROLLER BASED REMOTE CONTROLLED CAR JACK WITH ILLUMINATION SYSTEM

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Abstract: Car jacks are necessary when changing a flat tire or raising any part of the car. Unfortunately, available screw and hydraulic jacks are manually operated thus requiring more physical effort on the part of the user, and creating difficulties for people especially at night when there is no source of illumination. Although there are several works on automated car jack, this work incorporates something new by displaying the height of the jack at any instant during use, with the help of an LCD. The design consists of the transmitter and the receiver unit. The receiver unit is powered by the internal car battery (12V) or through the 12V cigarette light adaptor in the car. The transmitter unit uses 9V DC battery. The receiver unit consists of a DC motor, gear system and a screw jack. The gear system was integrated into a DC motor to reduce the speed of rotation because the system requires a high torque but low speed during operation. A display unit was incorporated in the transmitter unit to show the current height of the jack. A light source was added to the jack to provide lighting during use at night. After construction, it was used on different vehicle models and it worked satisfactorily as it was able to raise and lower loads of up to two tons (2tons). The jack also provided light through the LED's that was attached to the receiver unit and also the height of the jack was displayed during the raising and lowering process.

Keywords: DC motor, Gear, microcontroller, receiver, screw jack, transmitter

Introduction

Changing a car tire is not an easy task for most car users to do, most especially aged persons and female drivers. This is because of the high man power required to operate these jacks. A lot of vehicle owners have been stranded on their way and some others have had to wait for long periods of time for help from other either other road users or benevolent passers-by before they can change their tire. This is not a convenient experience for most vehicle users. If you have a flat tire by a dark road side at night, you will need to illuminate the area as much as possible before you can easily change the tire. So there is need for one to have a jack that can provide light within the area that is to be lifted at night time.

A car jack is a device used to lift a car so that maintenance can be performed. Jacks are basically used in raising cars so that a tire can be changed and also used when carrying out maintenance under the car (Manoj, 2014). A Car jack is an important tool that will be needed by every vehicle owner at one point or the other when carrying out repair or replacement.

The first car jack was patented in 1918 by Miller Falls Automobiles in Miller Falls, Massachusetts. In terms of design, it was similar to a bottle jack, with a lifting peg that was positioned under the car's chassis. The screw on the jack was then turned and the jack made contact with the vehicle chassis and the car would be lifted upward. The jack will be stopped when the vehicle is lifted enough the ground for repairs to be carried out. Unfortunately, as new model of cars were produced, this jack could not support the weight of these cars. This jack was then replaced by the scissor jack as the modern standard.

There are basically two kinds of car jacks. They are hydraulic and screw types. The screw type includes the scissor jack and bumper jack. The scissor jack uses a metal bar that is inserted into the jack to raise or lower it. When the metal bar is turned in a clockwise direction, the screw lifts the metal cylinder and platform on it. The metal bar will then be turned until the jack gets to the desired level (Egwerome *et al.*, 2014). The major problem with the scissor jack is the low weight limit.

Fig. 1: Scissors jack

The hydraulic jack uses hydraulic power to lift up several tons of loads. The history of hydraulic jack is dated to 1851, when Richard Dudgeon was granted patent for the hydraulic jack (Asonye *et al.*, 2015), which proved to be more superior to the screw jacks that was in use at that time. The types of hydraulic jacks include hydraulic bottle jack and hydraulic floor jack. They are usually rated according to the maximum lifting capacity (Balkeshwar & Anil, 2015). Hydraulic jack uses an incompressible liquid that is forced into a cylinder by a pump plunger (Asonye*et al*., 2015). The lifting up and down of the plunger through the small handle, results in the build up of pressure inside the cylinder, thereby lifting the top post and the car resting on it.

Fig. 2: Hydraulic bottle jack

This paper analyzes the design and construction of a microcontroller based remote controlled car jack with illumination system to provide light during use at night and a display unit incorporated into the design in other to make it user interactive, the display unit also displays the height of the jack during the lifting and lowering process. The organization of this paper is as follows. Section I explains the nature of problem, history, types of car jack and previous work. Section II deals with design method, analysis and function of each of the unit shown in the block diagram. Section III explains the main component used in the design process. Section IV shows the design calculation, consideration and working principle of the device. Section V explains the result obtained and the discussion. Finally, section VI summarizes the conclusion.

Related Works

Over the years, a lot of works have been done to improve the car jacking system and also to make it easier for women drivers and aged persons to use with lesser human effort. A brief review of several designs of systems that have been researched and implemented are presented below.

Asonye *et al.* (2015) designed a remote controlled system that can be used for hydraulic jack. The design consists of a base, gearing system and crank mechanism. The jack is powered by a 12v battery or through a lighter adapter in the vehicle. The lifting mechanism is made up of the motor with gearing system. To lift equipment you press the button on the remote so as to lock the hydraulic jack valve, and then you press the button again to start the lifting process until you arrived at your required height. The lack of illumination system to provide lighting during use at night and also the non provision of display unit in the transmitter unit to display the height of the jack during the raising and lowering process is a major drawback of this design.

Manoj *et al*. (2014) introduces an electric motor in the power screw, connecting gear with pinion, the electric switch connected to the DC motor and plugged to the automobile 12v battery source to generate power for prime mover (DC motor). When electrical power flows, the power screw is rotated through its gear and as the screw of the jack rotates the jack moves up.

Akinwomi & Mohammed (2012), added an electric motor in the screw jack for easy lifting of load. When an electric current flow through the cigarette lighter adapter connected to the motor, the motor transmits rotating speed to the gear mesh with the other gear connected to the power screw to be rotated. A 12V battery source was used to generate power for motor.

Egwerome *et al*. (2014) designed a system with a dc motor attached to the hydraulic jack to raise the jack. The system consist the transmitter and the receiver circuit. The receiver on reception of the transmitted infrared beam, amplifies and then demodulates the signal and the microcontroller sends out the signals for upward movement of the jack. The transmitter unit consists of an infra-red device that sends out a coded frequency to the receiver. The receiver circuit on receiving the transmitted infra-red beam, decodes the control signals for the upward movement of the car jack. To control the jack downward you have to manually adjust the valve at the base of the jack.

Balkeshwar *et al*. (2015) incorporates an electric motor in the screw to make load lifting operation an easy one. The motor is connected to 12V battery source. The motor transmits it rotating speed to the power screw with required speed reduction and increase torque. The adjustment of the height of the jack can be achieved by turning a lead screw and this can be done manually or through an electric motor.

Pandra&Ramanjulu (2015) used power screw to convert rotary motion into translator motion. When an electric power is applied to the wiper motor when plugged to the 12V battery in the car, the power screen will be rotated through its pinion (Gaurav *et al*., 2014). The jack will lift a vehicle in contact when the power screw is rotated through its connecting gear with the pinion. The motor transmits its rotating speed to the pinion gear meshing with the bigger gear connected to the power screw to be rotated with speed reduction and increased torque to drive the power screw. The switching circuit connected to the motor controlled the lifting and lowering process of the jack.

Design Method

This section deals with the design method and the analysis employed in the design of the microcontroller based remote controlled car jack with illumination. The block diagram of the design of microcontroller based remote controlled car jack with illumination is shown in Fig. 3.

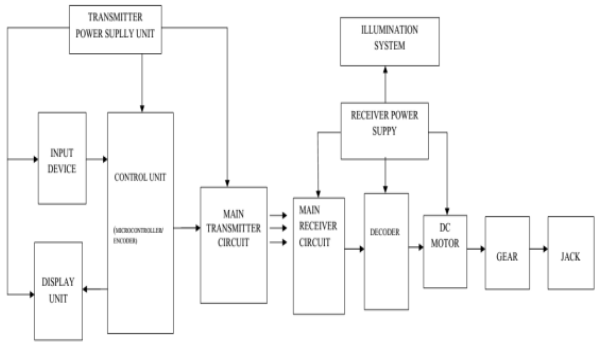


Fig. 3: Block diagram of the design

This block diagram has a transmitter power supply unit which is made up of a 9V battery for its power supply and a switch for power control. The transmitter part requires a 5 volts power supply. Therefore, it has a voltage regulator to regulate to 5V DC.

The input system consists of switches and its function is to send input to the microcontroller.

The display unit is the user interface. It serves as an interface between the user and the system. A 16 X 2 LCD was used in this design. The LCD is used to display the current height of the jack during the upward and downward movement of the jacking process.

The control unit consists of the microcontroller and the encoder. The microcontroller unit circuit is the heart of the design. This is where the program for the control part of the project is written and burned using assembly language and a universal programmer, respectively. The function of the microcontroller is to control and coordinates the entire circuit. One of the advantages of the microcontroller is that it makes the system/circuit less dependent on discrete components. The encoder converts the signals from the microcontroller into serial set of signals, which will then be transmitted serially through RF to the receiver unit.

The main transmitter circuit is used to wirelessly transmit data to the receiver. This unit consists of the RF control transmitter and other circuits. The function of this is RF transmitter is to transmit an RF signal to the receiver unit.

The main receiver circuit consists of the RF receiver. The function of the receiver circuit is to receive the transmitted serial data from the transmitter unit.

The receiver power supply unit has a 12V battery for its power supply and a switch for power control. The receiver unit requires a 5 volts power supply. Therefore, it has a voltage regulator to regulate to 5V DC.

The illumination system provides the required lighting and allows the user to use the jack at night. It consists of sun bright LEDs. The design is carried out in such a way that the light can be controlled independently. The illumination system consists of LEDs interconnected together to provide illumination at night.

The DC motor required for this particular design is expected to transmit a high torque at low speed, so as to raise and lower the vehicle gradually during the lifting and lowering process. Therefore, based on these requirements the DC motor used in the design as the following specifications: 12V DC motor**,** Power = 500W, Speed = 1450 rpm.
The car jack used in this work is the screw car jack.

Main components for the design

12 Volts DC battery was used as the source of power at the receiver circuit design. 9 Volts DC battery was used at the transmitter circuit design. Direct current is produced by sources such as batteries. The battery is the primary "source" of electrical energy used in vehicles today.
The power source of the circuit will be obtained from the car battery which is +12V dc. To obtain a regulated +5V, a 7805 voltage regulator was used in the design to get the required +5 voltage.Voltage regulator is used convert varying input voltage and produces a regulated output voltage. They are available in a variety of outputs. The most common part numbers start with the number 78 or 79 and finish with two digits indicating the output voltage. The 78XX series of voltage regulators are specifically designed for positive input voltage while the 79XX series is designed for negative input voltage.
The 8952 uses the clock signal provided by the crystal to synchronize its operations. The 8952 operate using what is called "machine cycles". The minimum amount of time in which a single 8952 instruction can be executed is referred to as machine cycle. A machine cycle is 12 pulses of the crystal. A 12 MHz crystal was used in this work.
The period of one clock cycle pulse = $\frac{1}{F} = \frac{1}{12MHz}$ =83.3 ns
Since one machine cycle consists of 12 clock pulses, hence it duration is 83.3ns × 12 = 1μs
The quartz crystal is connected across input XTAL (pin 18) and XTAL (pin 19) of the 8952 microcontroller. Two capacitors, 33 pF each are connected to the crystal to make it impossible for frequencies other than that generated by the crystal to penetrate the 8952.
The 8052 microcontroller hardware circuit is usually a very flexible one and all the surrounding components are given a recommended range of values, by the datasheet but the actual values can be chosen by the programmer.
The values used in the design are as follows
1 Reset capacitor (C_1): 10 μF
2 Reset resistor (R_1): 10 KΩ
3 Crystal oscillator (X_1): 12 MHz
4 Crystal capacitors (C_2 & C_3):33 pF
5 Pull-up resistors (R_5 to R_9): 1 KΩ

Design calculation

Transmitter power supply unit

The transmitter circuit uses 9V battery for its power supply and a switch for power control. A 7805 voltage regulator was used to obtained a regulated 5V DC that was used by the circuit. The transmitter part requires a 5 volts power supply.
(Battery) B1: The battery used is rated 9v

$$V_{min} = V_{out} + V_{ref} \qquad (1)$$

where
V_{min} is the minimum input voltage
V_{out} is the expected output voltage (5V)
V_{ref} = 2 or 3 (from 7805 datasheet)
Substituting into (1)
V_{min} = 5 + 2
V_{min} = 7V
V_{max} is the maximum input voltage (from 7805 datasheet V_{max} = 32V)
V_{max} = 32V
Since
V_{min} = 7V and V_{max} = 32V
Therefore, the voltage range falls between 7V to 32V
Therefore, B1 is suitable
B1 = 9V

For the switch (S_1)

The total current is less than 100mA
Therefore, S_1= 5A
Optional transient capacitor (C1): Data sheet of 78XX voltage regulator stipulate it to be 100 μF or above
Therefore C_1= 100 μF

Design calculations for current limiting resistor

R1 is the current limiting resistor that protects the LED. The value is chosen from the formula

$$R_X = \frac{V_S - V_D}{I_D} \qquad (2)$$

$V_S = 5V$ (Supply voltage)
V_D = 2V (Voltage through the LED)
I_D = 10mA (current through LED (10 – 20 mA))
Substituting into equation (2)

$$R_X = \frac{5-2}{0.01}$$

R_X = 300 Ohms
330 ohms resistor was used because it is the closest and available resistor

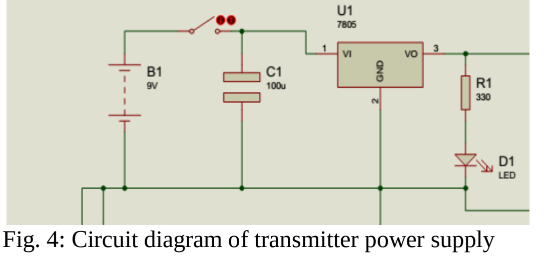


Fig. 4: Circuit diagram of transmitter power supply

Receiver power supply unit

(Battery) B1: The battery used is rated 12v. This is the standard battery voltage of most cars.
From equation (1)

$$V_{min} = V_{out} + V_{ref} \qquad (1)$$

where
V_{min} is the minimum input voltage
V_{out} is the expected output voltage (5V)
V_{ref} is reference voltage (from 7805 datasheet V_{ref} = 2 or 3)
Substituting into (1)
V_{min} = 5 + 2
V_{min} = 7V
V_{max} is the maximum input voltage (from 7805 datasheet V_{max} = 32V)
V_{max} = 32V
Since,
V_{min} = 7V and V_{max} = 32V
Therefore, the voltage range falls between 7V to 32V
Therefore, B1 is suitable
B1 = 12V

For the switch (S_1)

The total current is less than 100 mA
Therefore, S_1= 5A
Optional transient capacitor (C1): Data sheet of 78XX voltage regulator stipulate it to be 100 uF or above
Therefore C_1= 100 μF
R1 is the current limiting resistor that protects the LED. The value is chosen from equation (2).

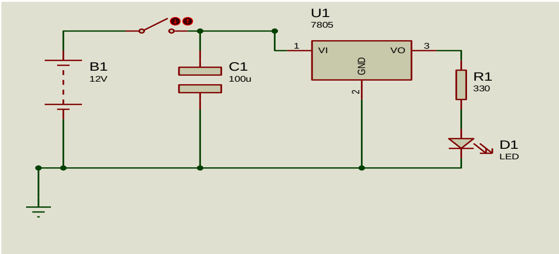
$$R_X = \frac{V_S - V_D}{I_D} \qquad (2)$$

$V_S = 5V$ (Supply voltage)

$V_D = 2\text{V}$ (Voltage through the LED)
$I_D = 10$ mA (current through LED (10 – 20 mA))
Substituting in (2)

$$R_X = \frac{5-2}{0.01}$$

$R_X = 300$ Ohms
330 ohms resistor was used because it is the closest and available resistor



Fg. 5: Circuit diagram of receiver power supply

Illumination circuit

This is the circuit that allows the user to use the jack at night. The design is carried out in such a way that the light can be controlled independently. The illumination system consists of LEDs interconnected together to provide illumination at night. To prevent higher current from entering LED that may in turn damage it, a biasing resistor is used. The value of the resistor is shown in equation (4).

R1, R2 and R3 are current limiting resistor
For the LED we choose from the range of 10 – 20 mA
In this design 20mA was used for higher brightness.

$$R_X = \frac{V_S - (V_D)T}{I_D} \qquad (3)$$

$V_S = 12\text{V}$ (Source voltage)
$V_D = 2\text{V}$ (Voltage drop across LED)
$I_D = 20\text{mA}$ (Current in LED)
T =3 (Number of LED in series)
Substituting into equation (3)

$$R_X = \frac{12-(3)2}{0.02}$$

$R_X = 300\ \Omega$

Design calculation for base resistor

R8 = Base resistor (R8 is the same as RB)
Base resistor formula is given by:
$R_B = 10\ \text{x} R_C$ (4)
Where R_C = R4 // R3 // R2
But R4 = R3 = R2 = 100 Ω
Where: $R_C = 100\ \Omega$
Substituting into equation (4)
$R_B = 10 \text{ x } 100$
$R_B = 1000\ \Omega$
Therefore R8 = 1000 Ω= 1 KΩ

Motor control

This is the circuit that controls the jack upward and downward.
R_5andR_7 are base resistors
$R_B = R_5 = R_7$
Using equation (4)
$R_B = 10 \text{ X } R_C$
$R_B$is base resistor
R_C = Resistance of the coil of the relay (400 ohms from datasheet)
Substituting into equation (4)
$R_B = 10 \text{ X } 400\ \Omega$
=4000 Ω
4.7 Kohms was used because it is the closest and available resistor

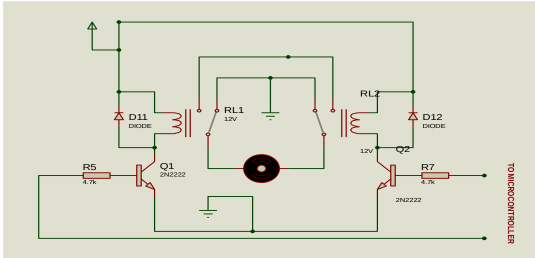


Fig. 6: Circuit diagram of motor control

RF Module (RX – TX) 434 MHz

The RF module comprises of an RF transmitter and RF receiver operating at a frequency of 434 MHz. A receiver can receive these signals only if it is configured for that frequency. The RF transmitter receives serial data and transmits it wirelessly through its antenna to the receiver unit. The RF receiver operating at the same frequency receives the transmitted data. A pair of encoder/decoder was used along with the RF module.

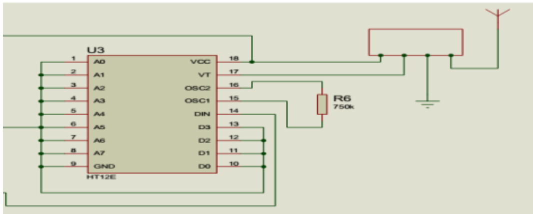


Fig. 7: Circuit diagram of RF transmitter

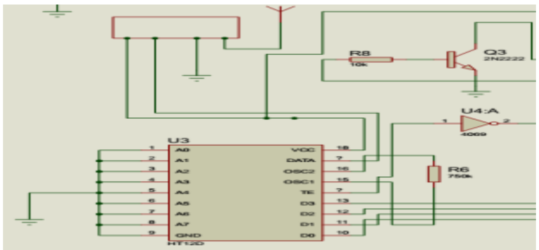


Fig. 8: Circuit diagram of RF receiver

HT12E dncoder/HT12D decoder

HT12E encoder/HT12D decoder is mainly used in interfacing RF and infrared circuits. HT12E encoder converts the parallel input into serial output while the HT12D decoder converts the serial input into parallel outputs and sends them to output data pins.

Car jack

The car jack used in this work is the screw car jack.

Flowchart of the microcontroller based remote controlled car jack with illumination system

The system flowchart is shown in Fig. 4. From the flowchart diagram, the system initializes once start button is pressed. After the initialization process, if the UP button is pressed on the transmitter, the signal is transmitted to the receiver on the other end. The receiver upon receiving the signal transmits the data to the decoder, the decoder then decode and energies the relays that controls the DC motor for the upward movement of the jack. If the UP button is continuously pressed, this will result in steady lifting of the jack. On the other hand, if the DOWN button is pressed, the transmitter will be activated and signal will be sent to the receiver, the receiver on receiving the signal transmits it to the decoder that decodes and energies the relays that controls the DC motor for the downward movement of the jack. A continuous pressing of the DOWN button will result in steady dropping of the jack.

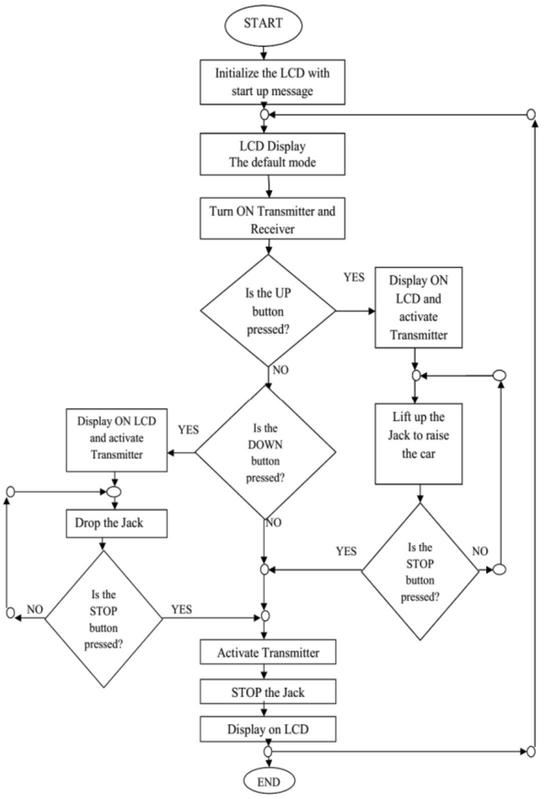


Fig. 9: Flowchart of the microcontroller based remote controlled car jack

Working operation of the device

The system is made up of two circuits – the remote control part which is the transmitter and the jack control part which is the receiver. Both are battery powered.In the transmitter part, the components include the microcontroller, LCD screen, RF transmitter, encoder IC as well as other discrete components. The circuit has a 9V battery for its power supply and a switch for power control. The transmitter part requires a 5Volts power supply. Therefore, it has a voltage regulator to regulate the voltage to 5 volts D.C. The circuit has 3 input buttons; the up, down and stop buttons. The microcontroller uses the up button to send signals via the RF transmitter, to the jack circuit to raise the jack. The down buttons to drop the jack and the STOP button to stop the Jack. The LCD screen displays the status of the system at every point in time. When the transmitter unit is turned ON and any of the three push buttons are pressed, the signal will be sent to the microcontroller; the microcontroller reads the signals and in turn sends it to the encoder. The encoder then converts the parallel data into serial data. The serial data is then send to the RF transmitter to transmits it wirelessly to the receiver unit.

The receiver unit operates on a 12V battery power with a switch for control. A voltage regulator to regulate the voltage to the required 5volts D.C was added to the circuit. The receiver unit receives the transmitted serial data through the RF 434 MHz receiver. The serial data will then be sent to the decoder to decode and convert the serial data to parallel data. The decoder decodes the signal and then activates the transistor that energies the relays that effects the clockwise and anticlockwise bi-directional movement of the jack. For night operations, the system has LEDs connected to it for illumination.

Result and Discussion

The results of the test that was carried out on different vehicle models showed that the jack was able to lift and lower loads of up to 2 tons. The vehicles models tested include Toyota Camry, Honda Odyssey, Toyota corolla and Volkswagen Golf 4. The maximum time used to lift these vehicles model are 184 sec for Toyota Camry, 193 sec for Honda Odyssey, 188 sec for Toyota Corolla and 160 sec for Volkswagen Golf 4. The measured height of the vehicles lifted above the ground was between 12 and 17 cm. The LED's that was attached to the receiver provided the required illumination during usage at night. The LCD at the transmitter displayed the height raised or lowered during the jacking process.

Fig. 10: Microcontroller based remote controlled car jack with illumination system prototype

Conclusion

The need for the improvement of the existing car jack is long overdue. This design work has contributed a lot towards the improvement of existing car jack thereby making it easier for vehicle operators especially aged persons and female drivers to use car jack with ease. The design was carried out in such a way that the jack can be controlled using a wireless device so that jacking can be done at any convenient position. The jack is easily movable and also provides a light source so that the jack can be use at night. The LCD attached to the transmitter unit displayed the height of the jack during the raising and lowering process, thereby making it user interactive. There are car jacks that can be operated electrically, but this jack cannot be controlled remotely and are difficult to use at night because there is no source of illumination. Hence this work is to improve on the existing electrical jack and to minimize the human effort applied while operating the jack in order to save time and human effort.

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