Design and Implementation of an Electric Wheel-Chair to Economize it with Respect to Bangladesh

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***Abstract*—This paper evaluates the affordability and cost-effectiveness of Economy Priced Electric Wheel Chairs (EWC) for the disabled people of Bangladesh who are financially challenged. After successfully upgrading a normal wheel chair into a joystick-controlled electro-mechanical wheel chair, the cost is reduced to an achievable US $400 compared to minimum US $1100 in United States according to a market survey. It is possible for cheap and available tools found in Bangladesh which prove sufficient for the upgrading process. A microcontroller based control system is applied with two dc gear motors to control the rear end wheels. The prototype project indicates great success not only in business sector but also reassures disabled people a better life. Various technologies have been used to make this electro-mechanical device, leaving room for further developments considering the versatility of the microcontroller (PIC18F4520) used in it.**

***Keywords*— Control System, Cost-Effective Electro-Mechanical, EWC and Microcontroller**

I. INTRODUCTION

In worldwide context, an estimated 100-130 million people with disabilities need wheelchairs. Experts predict that the number of people who need wheelchairs will increase by 22 percent over the next ten years [1]. Wheel-chair is still the best transportation means for them since its invention in 1595 (called an invalids chair) for Phillip II of Spain by an unknown inventor; and this is the reason why this particular chair with wheels is developing in newer shapes with additional latest enhancements following its conversion into an electric one. This paper details the project about an electric wheel-chair (EWC) which is much more comfortable and flexible for movement compared to a normal wheel-chair and also costs 60-70% less compared to the available or regular EWCs [2]-[3].

In USA, almost 200,000 physically challenged people use electric wheel-chair for their daily life needs. On the other hand, in Bangladesh handicap people still depend on the old formatted normal wheel-chair as major portion of this poor country cannot afford the huge cost of a basic electric wheel-chair. The paper dictates the main objectives of the performed project such as to run the wheelchair automatically in all possible directions forward, backward, left and right by using a joystick. A 40-pin PIC18F4520 micro-controller was operated smoothly to ensure EWC's movement in desired direction, after receiving command signal from the joystick. Each rear wheel of EWC is attached with a DC gear motor which acquires required power from dry-cell battery connected to respective motors [1]. Among all the merits, there are a few drawbacks especially when the wheel-chair moves in reverse direction. The EWC operation during reverse-bias is not that smooth compared to other direction operations.

II. OBJECTIVES

The aim of this project was to design the prototype and it is as follows:

- Collection of all the equipments and materials required for overall wheel-chair enhancement setup.
- Forming of a light-weight wheel-chair structure which would carry up to 100kg (human bodyweight plus equipments).
- Successfully coding of a specific program, which would run the device directionally by using a joystick (controlled by a micro-controller).
- Implementation and connection of all the equipments like motors, micro-controller, and joystick together.
- Making the total prototype as cost-effective and less expensive as possible.

III. BLOCK DIAGRAM

The system block diagram is shown in Fig. 1.

The system block diagram shows how the command from the EWC user is sent via the joystick to the Microcontroller chip. Then following the instructions coded in the chip the respective optocouplers will be activated and using the H-Bridge module the DC Gear Motors are started.

IV. EQUIPMENTS AND TECHNIQUES

For this prototype to be build both electrical and electronic components were required [1]. Some of the parts are briefly

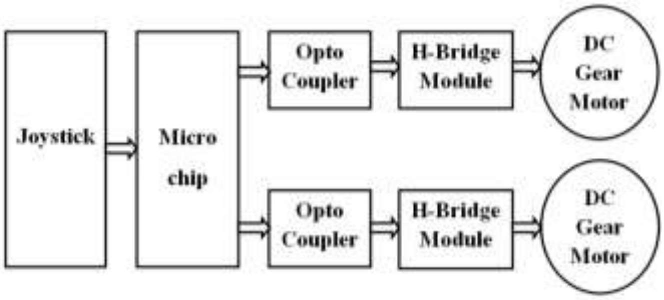


Fig. 1: Block diagram showing the flow of command in the EWC

described as follows [3]:

DC gear motor*:* it is a specific type of electrical motor that is designed to produce high torque while maintaining a low horsepower, or low speed motor output. Gear motors are commonly used in conveyor-belt drives, home appliances, in handicap and platform lifts, medical and laboratory equipments, machine tools, packaging machinery and printing presses. They reduce speed in a series of gears and in turn create more torque. So it is space-saving, reliable and durable, consumes low energy and has small vibrations to name a few advantages.

PIC18F4520: it is the type of micro-chip we needed because of its multi-purpose functionality. It is an 8-bit microcontroller of PIC18 family. This is a 40 pin Microcontroller consisting of 5 I/O ports. It is an advanced microcontroller consisting of 32 KB flash memory.

MOSFET (Metal Oxide Semiconductor Field-Effect Transistor)*:* it is a common type of transistor in which charge carriers like electrons flow along a channel. It is a voltage controlled device and there is a very thin layer of silicon dioxide for insulation to prevent the current from flowing between the gate and channel. This channel is also known as the inversion layer. No gate current is required to maintain the inversion layer at the interface since the gate oxide blocks any carrier flow. MOSFETs are useful for high-speed switching applications and also in integrated circuits.

BJT (Bipolar Junction Transistor): consisting of three terminals, it is a current controlled device. It is used as current amplifiers and also as voltage amplifiers, besides being used as switches, buffers or impedance matching devices and regulators.

Opto-coupler: it is an opto-isolator, and it is a component that transfers electrical signals between two isolated circuits using light. Opto-couplers prevent high voltages from affecting the system receiving the signal. Commercially available opto-isolators withstand input-to-output voltages up to 10 KV and voltage transients with speeds up to 10KV/µs. Common type of opto-couplers consists of an LED and a phototransistor in the same package. It is usually used for transmission of digital signals, but some techniques allow use with analog (proportional) signals.

Joystick: it is an input device consisting of a stick that pivots on a base and reports its angle or direction to the device it is controlling. It is also known as the control column. In order to communicate a full range of motion to the computer, a joystick needs to measure the position on two axes- the X axis (left to right) and the Y axis (up and down). Just as in basic geometry, the X-Y coordinates pinpoint the stick's position exactly.

Voltage Regulator: it is designed to automatically maintain a constant voltage level. A voltage regulator may be simple 'feed-forward' design or may include negative feedback control loops. It may use an electromechanical mechanism, or any electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

Crystal oscillator: it is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and also to stabilize frequencies for radio transmitters and receivers.

Heat sink: it is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. Heat sinks are used with high power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes, where the heat dissipation ability of the basic device is insufficient to moderate its temperature.

V. DESIGN ALGORITHM

In this design, two DC gear motor is connected between two H-Bridge module. The triggering pulse comes to the MOSFET of H-Bridge from MCU's Port D through Opto-coupler [1]-[2]. Opto-coupler is used to isolate the MCU unit from H-Bridge module. The power is connected to the H-Bridge module through another power MOSFET which is used as a switch. This switch is triggered by MCU's controlling signal coming from Port C2 pin which has a special function of CCP (Capture/Compare/PWM) thus regulating the power of the motor. Here an Analog joystick, the input device, is connected to Port B.

Two-axis analog joystick has two potentiometers. So based on this potentiometer's different values MCU take different actions. Joystick signals which are basically potentiometer's value go to the MCU for processing. Potentiometer's value lies between 0-255 since 8bit signal is used as input.

When both axis value is in neutral position then MCU gives no triggering signal to H Bridge so the motors remain idle.

When X-axis is in neutral position ($70<x<140$) and value of Y-axis is greater than 140($y>140$) then MCU triggers signal through Opto-coupler resulting both motors to rotate in clockwise direction.

When X-axis is in neutral position ($70<x<140$) and value of Y-axis is less than 70($y<70$) then MCU triggers signal and both motors rotates in counter-clockwise direction.

When Y-axis is in neutral position ($70<y<140$) and value of X-axis is greater than 140 then the MCU triggers signal through Opto-coupler resulting in motor 1 rotating in clockwise direction and motor 2 rotating in counter-clockwise direction.

When Y-axis is in neutral position (70<y<140) and value of X-axis is less than 70 then motor 2 will rotate in clockwise direction and motor 1 will rotate in opposite direction.

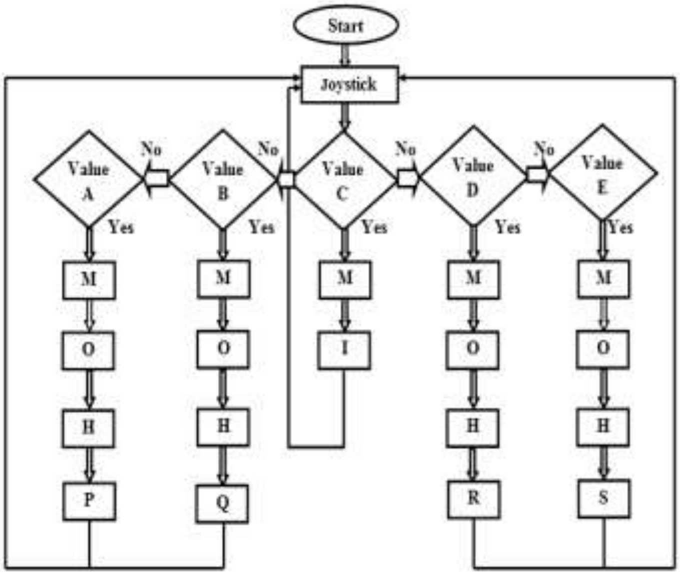


Fig. 2: Flow Chart of the instructions given to the microcontroller

The notations used in the flow diagram are given below:

(A) 140<x, 70<y<140

(B) x<70,70<y<140

(C) 70<x<140, 70<y<140

(M) Microcontroller unit, MCU

(D) 70<x<140y>140

(E) 70<x<140, y<70

(H) H-Bridge Module

(I) Motor Idle

(O) Opto coupler

(P) Motor 1 (+) ve, Motor 2 (-) ve

(Q) Motor 1(-) ve, Motor 2 (+) ve

(R) Motor 1, 2 (+) ve

(S) Motor 1, 2 (-) ve

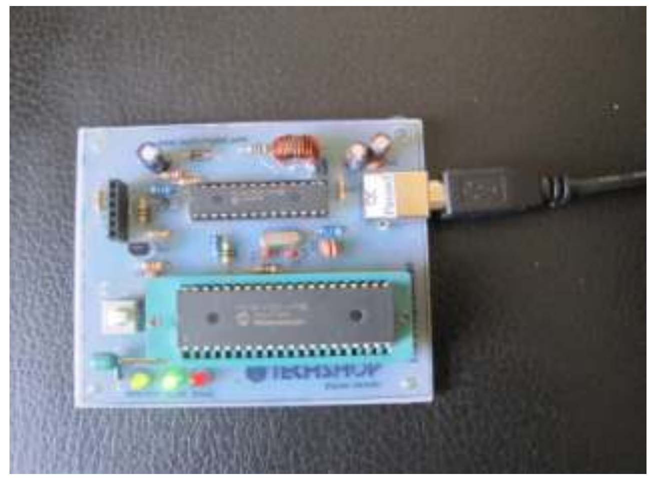
The flow chart shows how the Microcontroller unit is programmed and the instructions that it can follow. It also depicts the decisions that must be made by the microcontroller when commands are passed from the joystick to it. The motor bi-directional movement is controlled by these instructions.

VI. PROGRAMMING PROCEDURE

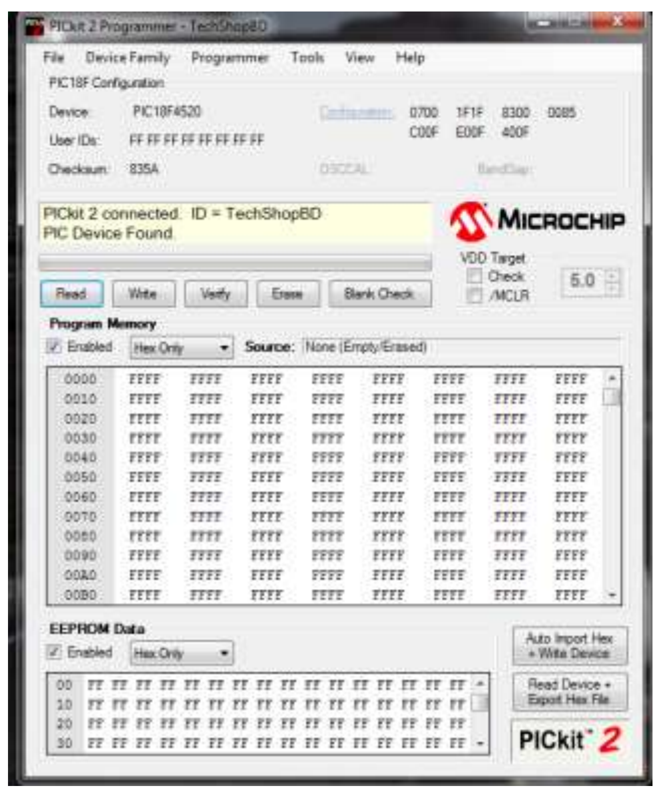
PICKit2 Burner is a USB in-circuit programmer and it can be used to program most of the PIC microcontrollers. It simply consists of a PIC18F2550 and a couple of passive components such as resistors, capacitors, LEDs etc. The programmer uses a firmware only USB driver and there is no need of a special USB controller. Using PICKit2 is easier and simpler. It just needs one step to finish the process which is to connect the PIC with computer and the microcontroller, then program it. PICKit2 has been designed with following capabilities and features:

- It works under multiple platforms. Linux, Mac OS X and Windows are tested.
- Its speed for the programming is up to 5kBytes/sec.
- Its option is supported to the targets with low clock speed.

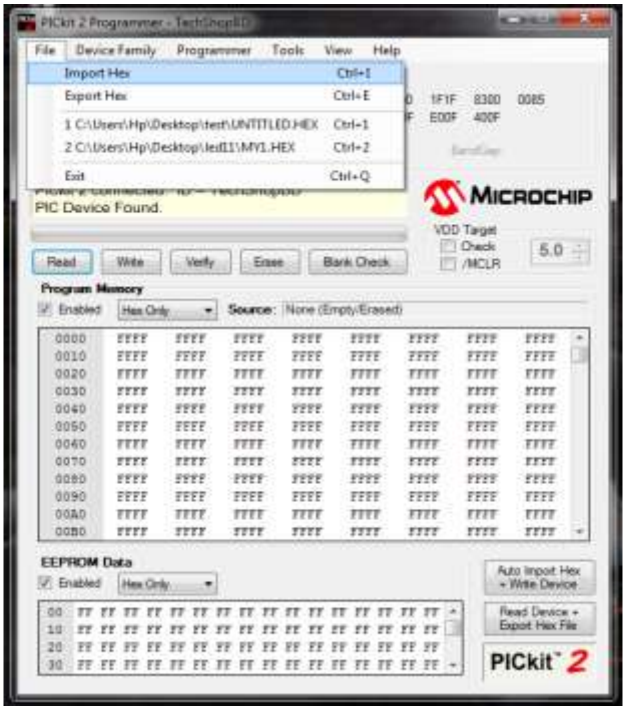
PICKit2 software is used to burn/download HEX file to desired MCU. The procedure is being illustrated next.



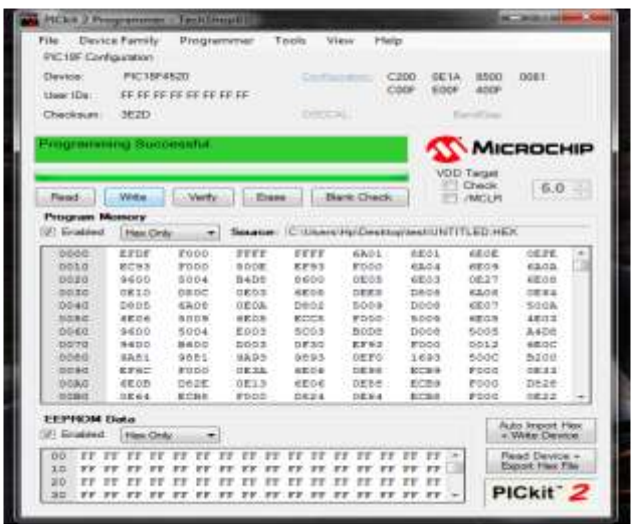
(a)



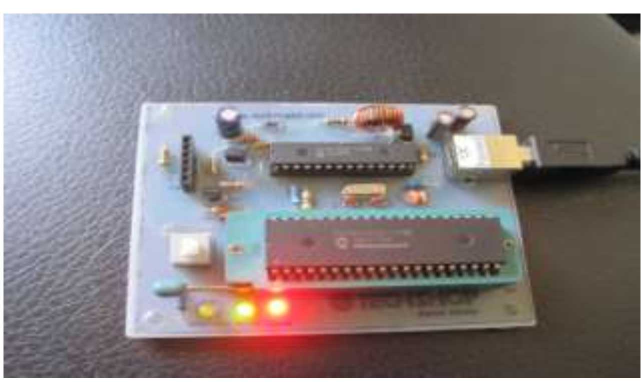
(b)



(c)



(d)



(e)

Fig. 3: (a),(b),(c),(d),(e) Burning process of HEX files for microcontroller

VII. STRUCTURAL DESIGN

A locally produced normal 'X' shaped foldable wheelchair was used to start as the basic infra structure of the prototype. The two front wheels of this wheelchair can be moved in any direction whether the rear wheels are moved or not by pushing them manually. It has manual braking lever.

The main components or parts of the bought wheelchair are the spindle, bearing, bushing, chain and sprocket.

- Spindle helps to rotate the back wheel on which the bearing and wheel is mounted.
- Bearing is a 'O' shaped structure which allows the shaft or spindle to rotate smoothly.
- Bushing is also 'O' in shape but its main purpose is to isolate vibration. It can be made of rubber or metal.
- The Chain is used to convey mechanical power from one position to another.
- The Sprocket is a toothed wheel which is used to transmit rotary motion in shafts. It is a simple, and reliable and efficient means of power transmission from motor to spindle or shaft.

Major change is done in this structural design. Instead of using common shaft, two modified Spindle is used in the EWC's wheels which are not connected. Available wheel chair in present market has got 6 inch long and 12 mm diameter's spindle in each rear wheel. But this design has got 12 inch 12 mm spindle. In EWC 4 bearings is used in each wheel. Two are 14 mm in diameter and two are 20 mm. The 14 mm bearing is used in pivot joint and 20 mm bearing is used in wheels. A Sprocket is mounted on the modified spindle.

This Sprocket is joined with chain which is connected with another smaller cassette that is mounted directly on motor shaft. Whenever the motor shaft rotates then the sprocket of rear spindle starts rotating and thus the wheel starts moving. In EWC the chain is used to transmit power to drive wheel from the dc gear motor. It consists of a series of short cylindrical rollers joined with each other by side links. In EWC the 'X' shaped rod is removed. An aluminum tray is soldered underneath the seat to mount the dc gear motor and battery. Two dry cell batteries are used for power. The control circuitry is placed underneath the seat which is covered in a box.

The joystick is mounted on the right handle of EWC. The power is coming from the battery which is distributed through wire. This wire goes to Control unit and is then connected to the motor. After completing the connection of the electro-mechanical equipments, the structure which is implemented in the wheel chair is given in Fig. 4.

Fig. 4: Electro-mechanical structure parts consisting of Batteries, Motors, Joystick and Circuit Board

VIII. TECHNICAL SPECIFICATION

Technical specifications of the wheel chair are given in Table 1:

TABLE 1
TECHNICAL SPECIFICATIONS OF THE PROTOTYPE

Parameters	Value
Battery	2 X 12V, 30Ah
Motor	2 X 24V DC Gear
Charging Time	7 Hours
Max. Driving Speed	Forward: 7km/h Backward: 4km/h
Max. Weight Capacity	120 Kg
Total Weight of EWC	41 Kg

After thorough market research the mechanical devices were selected and trial and error testing was done to find the maximum weight capacity. The driving speeds were obtained by driving the EWC in different directions.

IX. COST OF MAKING EWC PROTOTYPE

The components that were used and the services obtained, incurred an expense. The following Table 2 shows those charges of various equipments, and electromechanical devices. It also portrays the results obtained to justify the claim of reducing the price and hence economizing the EWC.

X. FINAL PROTOTYPE

After successfully placing all parts into the EWC as shown in Fig. 5, the system works remarkably within expectations. The final prototype is shown in Fig. 6, which can successfully carry a disabled person with a body-weight of maximum 100 Kilograms (Kg).

TABLE 2
COST INCURRED TO BUILD THE EWC PROTOTYPE

Parts	Quantity	Unit Price (BDT)	Subtotal (BDT)	Subtotal (USD)
Normal Wheel Chair	1	5,500	5,500	70.72
DC Gear Motor	2	7,500	15,000	192.87
Battery	2	3,000	6,000	77.15
MCU	1	250	250	3.21
MOSTET	8	100	800	10.29
Joystick	1	600	600	7.72
Others			600	7.72
Mechanical Equipments			2,240	28.80
Mechanic's fee			1500	19.29
Grand Total			**32,490**	**417.76**

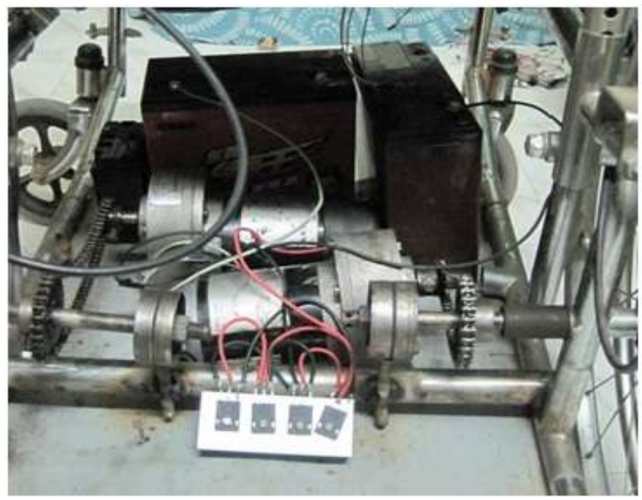


Fig. 5: All Equipments placed in wheel chair

Fig. 6: The completed prototype

XI. LIMITATION

This project's EWC prototype costs BDT 32, 490 (around US$ 400) which is evidently less than commercially available EWCs price tagged at US$ 1100 in the least. Still, there are opportunities to reduce the total cost of this project by undertaking it for mass production.

The total expense of this automated electro-mechanical device gets reduced by around BDT 10,000 when it is taken for mass production of 100 units of EWC. For 100 units of EWC, per unit cost of DC gear motor comes near BDT 4,500 and per unit cost of Battery will be BDT 2,000 whereas DC gear motor and Battery costs BDT 7,500 and BDT 3,000 respectively for just the production of a single EWC. Purchasing the required mechanical equipments in a whole, the project developer can reduce the mechanical expenses by 60% and mass production gives the authority a chance to build a wheel-chair structure in reduced price as well.

Therefore, the reduction in total expense occurs with the greater numbers of EWC units during mass production.

One of the largest limitations with regards to Bangladesh is the lacking of proper infrastructure available for disabled people. Seldom private and public buildings are seen having ramps, local transport do not have any scope for a person using a wheelchair to board the vehicle, unlike some countries (i.e., Singapore or United Kingdom)[1]. Also for a physically challenged person to move around freely on the streets of Bangladesh is again difficult due to road conditions, traffic and weather. During rainy season most roads become quite muddy and the EWC owner would require attaching specialized type of tires for better grip and arranging some kind of a hood to prevent rainfall.

XII. FUTURE WORK

There are plenty of scopes to upgrade this EWC prototype by adding features like Voice & Gesture recognition which provides ease of operation in the system that will be more user friendly [4-5]; Heart beat monitor which can detect the heart beat rate of the user as well as the sign of heart attack; GPS tracker to find out users exact location; and many more optional features can be added according to user's need.

XIII. CONCLUSION

This project resulted into a successful prototype of an Electric wheel-chair which costs around US$ 400 (BDT 32,490), where the minimum cost of an available EWC is around US$ 1100 in USA. This minimized expense is pretty affordable for most of the people of Bangladesh and it can be even cheaper when taken for mass production.

This project can also be counted as a brilliant initiative for the betterment of physically handicapped and disabled people's lifestyle.

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