KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY, KHULNA

Department of Electrical and Electronic Engineering

Sessional on Power Electronics and Industrial Drives (EE 4110)

PROJECT REPORT

on

“CLOSED LOOP SPEED CONTROLLER OF A PRIME MOVER FOR CONSTANT DC VOLTAGE GENERATION”

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Date of Submission: 03.06.2024

ABSTRACT:

In this article, a closed loop speed controller of a prime mover for constant voltage generation was proposed. It talks about what the control system aims to do and what parts are needed, including their specifications. The goal is to explain how the control system works. By enabling the motor to rotate in both directions and providing user-friendly interfaces, the control system improves the speed control of a prime mover for constant voltage generation. The report concludes by highlighting the importance of choosing the right components, using an closed loop system, and implementing control algorithms to ensure the speed control of a prime mover for generating constant voltage.

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OBJECTIVES:

- To build a DC drive system.
- To build a H-bridge power converter with the required parts.
- To control the speed of a prime mover using ARDUINO's PWM.
- To generate constant voltage using voltage divider circuit.

INTRODUCTION:

H-Bridge Converter:

An H-bridge converter is an electronic circuit that changes the direction of voltage applied to a load. It has four switches arranged in an H shape, with the load in the middle.

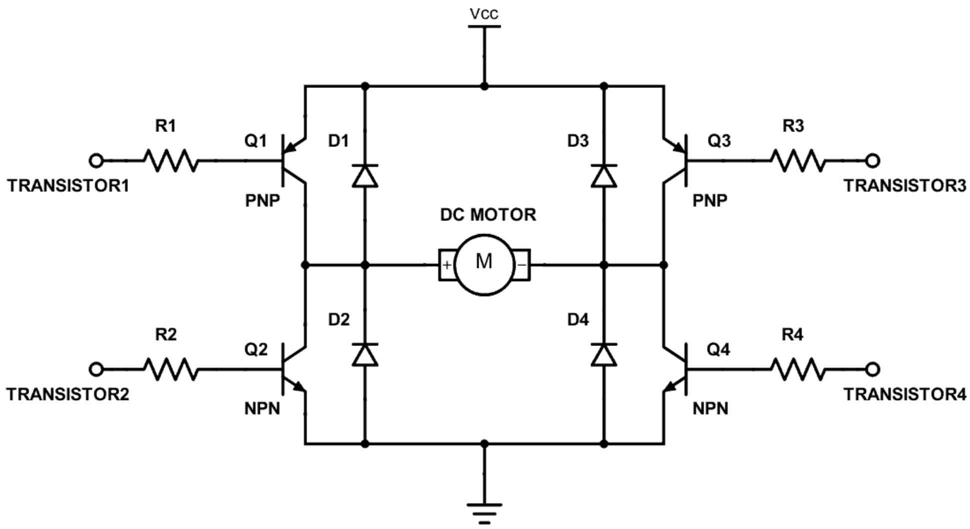

Fig 1: Circuit diagram of H-bridge converter.

● The switches are usually transistors, either bipolar or FETs, and sometimes IGBTs in high voltage cases. Some solutions integrate the switches with their control circuits, but this isn't always necessary. The diodes are usually Schottky diodes.

● The top of the bridge connects to a power supply (like a battery), and the bottom is grounded. All four switches can be turned on and off independently, though there are some limits. H-bridges are commonly used with brushed DC or bipolar stepper motors (steppers need two H-bridges per motor).

GENERATING PWM USING ARDUINO:

PWM (Pulse Width Modulation) is a technique where pulses of different widths are created. The width of the pulse determines how long the voltage stays HIGH or LOW for a given cycle. Longer pulses mean higher output voltage. PWM signals look like analog signals but are actually square waves that turn on and off quickly, creating the illusion of a continuous signal. Humans can detect flickering up to around 400Hz, while Arduino PWM signals are typically at 490Hz or 970Hz depending on the pin used. The Duty Cycle (%) indicates how long the pulse stays HIGH or LOW within a time period. For example, a 25% duty cycle in a 0.1-second period means the signal is HIGH for 0.025 seconds and LOW for 0.075 seconds. This signal's frequency would be 10Hz (1/0.1).

VOLTAGE DIVIDER CIRCUIT:

A voltage divider is a simple series resistor circuit. It's output voltage is a fixed fraction of its input voltage. The divide-down ratio is determined by two resistors.

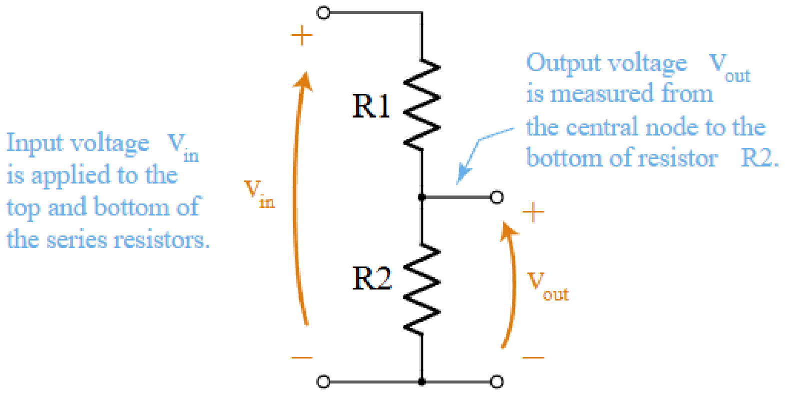

Fig 2: Voltage Divider Circuit.

ARDUINO MEGA:

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.

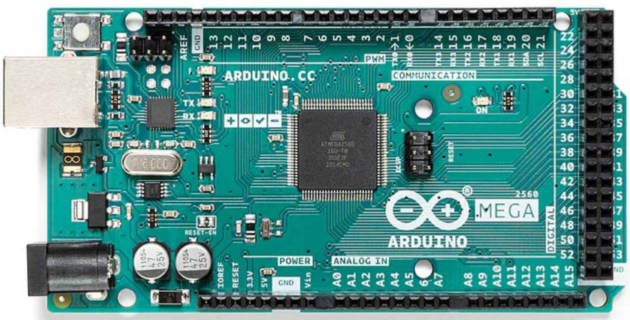

Fig 3: Arduino Mega

TLP250 DRIVER:

The TLP250 is a commonly used optocoupler or opto-isolator device that provides electrical isolation between input and output signals. It is often used in driver circuits to control high-power devices such as motors, relays, and power transistors. TLP250 has an input stage and an output stage. It also has a power supply configuration. It is more suitable for MOSFET and IGBT. The main difference between this and other MOSFET drivers is that it is optically isolated. It works like an optocoupler.

Fig 4: TLP250 Driver (Optocoupler)

Ratings:

- Operating frequency: 0-25kHz
- Input Supply voltage: 10-35 volts
- Output Supply voltage: 10-35 volts
- Output drive current: 1.5A
- Input Current: 10 mA

DC MOTOR:

A 12V DC motor is a type of electric motor that operates on 12 Volts of direct current (DC). These motors are commonly used in a variety of applications, including conveyor belts, elevators, cranes, and hoists. They are also used in automotive applications such as power windows and windshield wipers.

Fig 5: 12V DC Motor.

POWER MOSFET:

A power MOSFET is a specific type of metal–oxide–semiconductor field-effect transistor (MOSFET) designed to handle significant power levels. Compared to the other power semiconductor devices, such as an insulated-gate bipolar transistor (IGBT) or a thyristor, its main advantages are high switching speed and good efficiency at low voltages. It shares with the IGBT an isolated gate that makes it easy to drive. They can be subject to low gain, sometimes to a degree that the gate voltage needs to be higher than the voltage under control.

Fig 6: Power MOSFET

PWM SIGNAL:

Pulse Width Modulation (PWM) is important for motor speed control because it allows precise adjustment of the motor's speed without significant power loss. PWM controls motor speed by varying the duty cycle of the pulses sent to the motor, effectively controlling the average voltage and power delivered to the motor.

To vary the voltage level using PWM:

1. **Duty Cycle**: Adjust the duty cycle, which is the percentage of time the signal is "on" versus "off" during each cycle.
    - **Higher Duty Cycle**: More time "on" means higher average voltage, increasing motor speed.
    - **Lower Duty Cycle**: More time "off" means lower average voltage, decreasing motor speed.
2. **Switching Frequency**: Keep the switching frequency high enough to ensure smooth motor operation and avoid perceptible flicker or noise.

By controlling the duty cycle of the PWM signal, the effective voltage supplied to the motor can be varied, thereby controlling the speed of the motor efficiently.

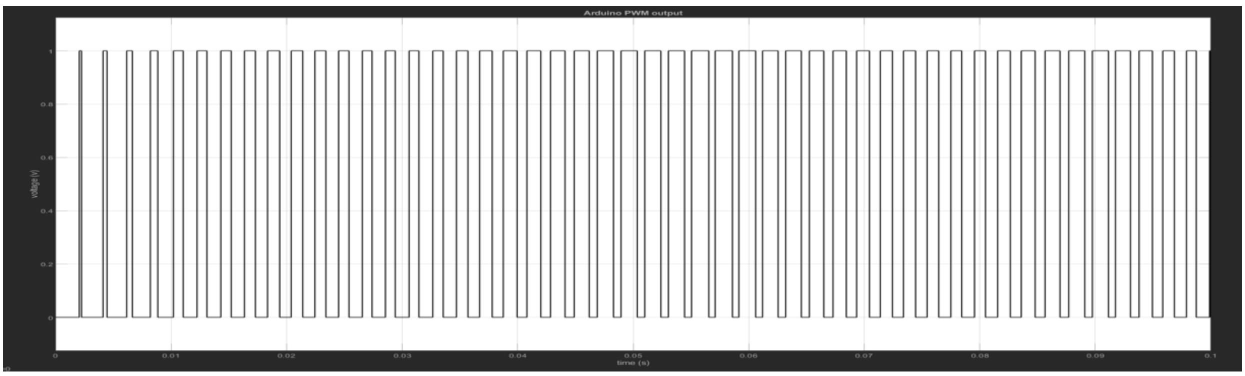

Fig 7: Arduino PWM Output

APPARATUS REQUIRED:

Sl. No.	Name of the apparatus	Ratings	Quantity
1	DC Motor	12V,12000rpm,0.6A	02
2	MOSFET (IRF3205) (IRFZ44N) (STD65NF06)	V_{DSS} = 55V, I_{DSS}=110A, $R_{DS(on)}$=8mΩ $V_{GS\ max}$ = 20V V_{DSS} = 55V, I_{DSS}=49A, $R_{DS(on)}$=32mΩ $V_{GS\ max}$ = 20V V_{DSS} = 60V, I_{DSS}=60A, $R_{DS(on)}$=14mΩ $V_{GS\ max}$ = 20V	04
3	TLP250 Driver	V_{CC} = 10-35 V, I_{CC} = 11 mA (max) I_{OUT} = 1.5 A(max), I_{Th} = 5mA	04
4	Arduino Mega 2560	Operating voltage = 5V Recommended Input voltage = 5-12 V Dc current in I/O pin = 20mA	01
5	Capacitor	100µF,50V	05
6	Resistor	1kΩ,10kΩ,56Ω,1W	30
7	Potentiometer	100KΩ,10KΩ,1W	03
8	Push Button	--	01
9	Breadboard	--	03
10	Connecting Wires	--	As required

CIRCUIT DIAGRAM:

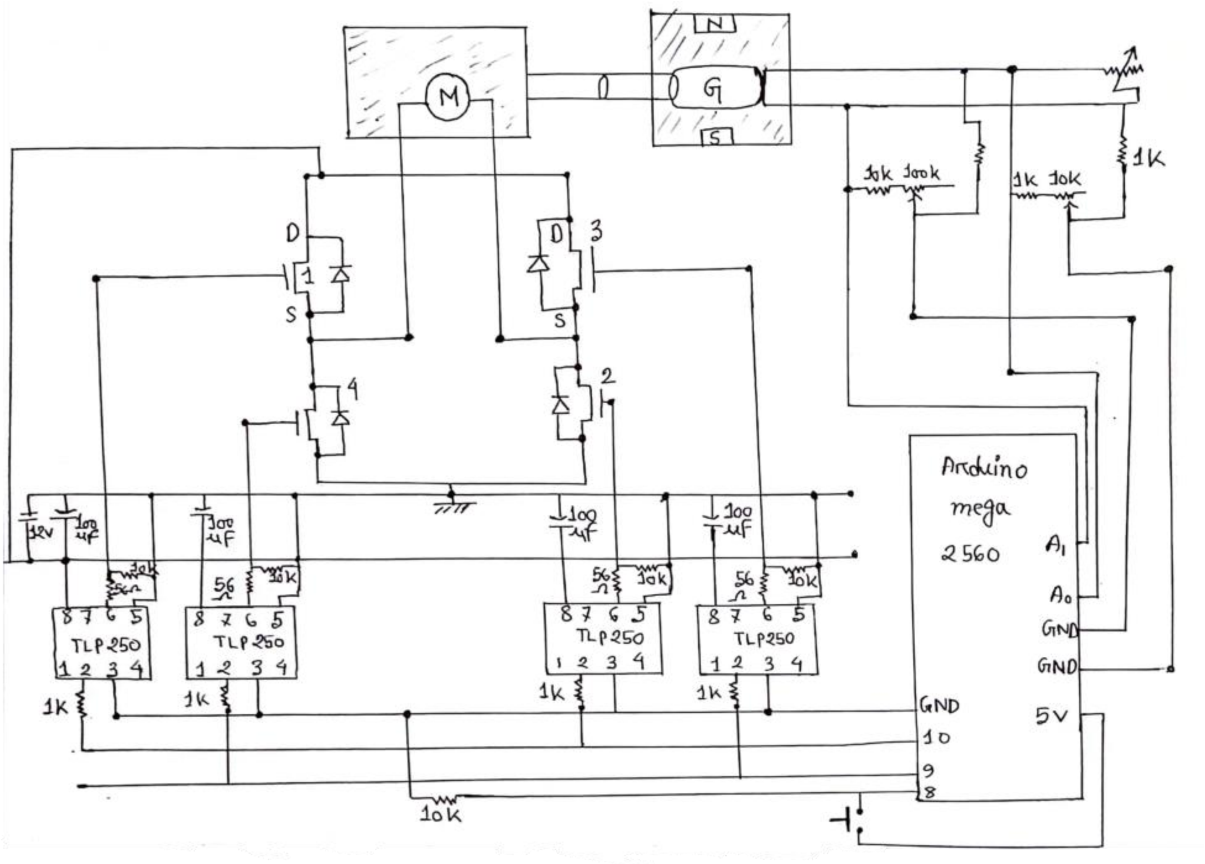

Fig 8: Circuit Diagram for the closed loop speed controller of a prime mover.

SIMULINK MODEL:

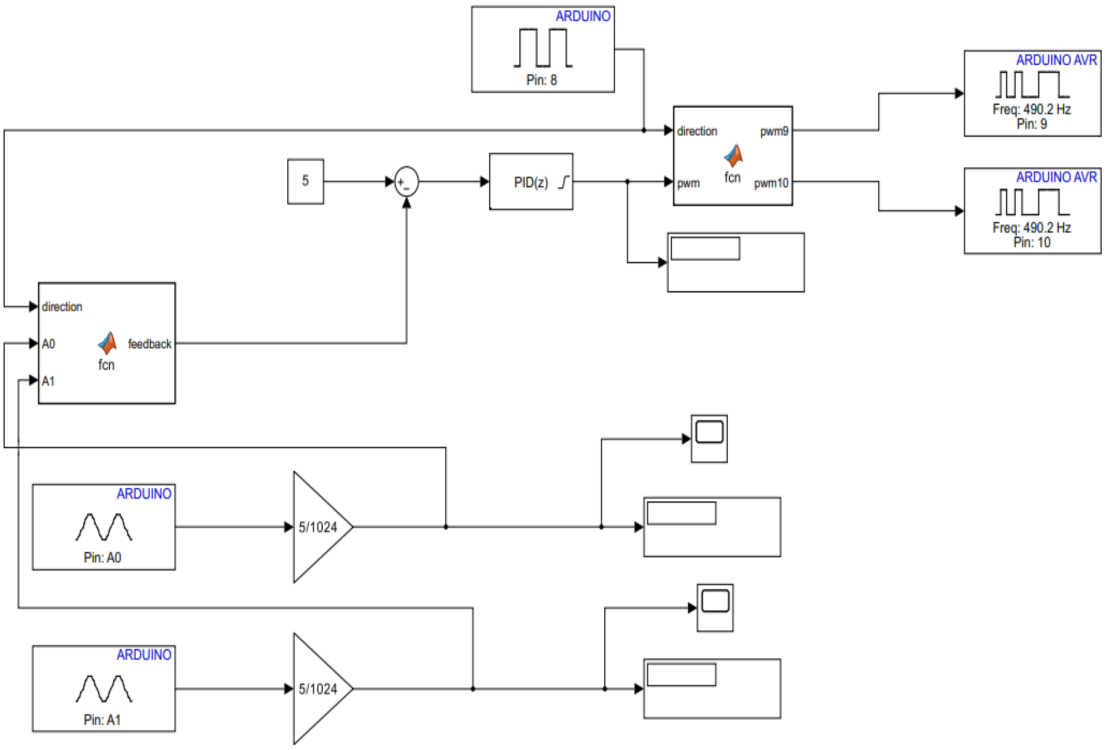

Fig 9: Simulink Model

EXPERIMENTAL SETUP:

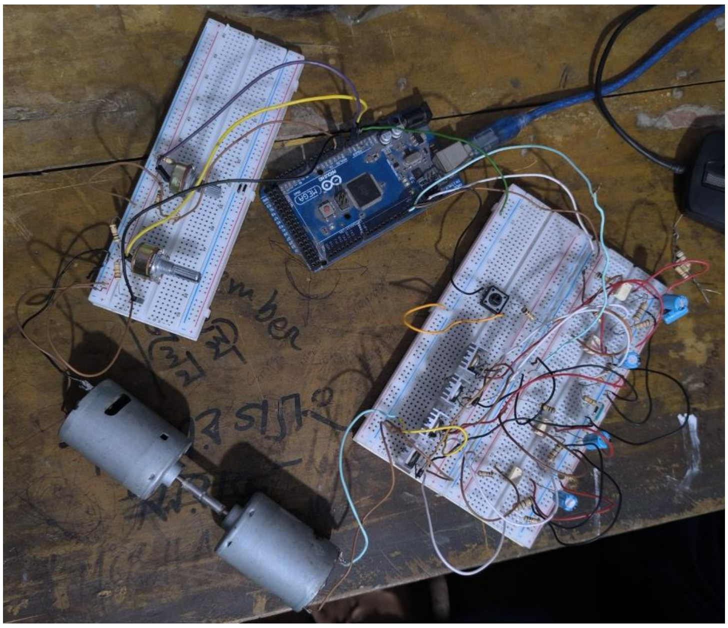

Fig 10: Experimental setup for the closed loop speed controller of a prime mover.

RESULTS AND DISCUSSIONS:

The main objective of this experiment was to create a closed loop system for controlling the speed of a prime mover to generate constant DC voltage. An Arduino controller is used to generate suitable switching sequence. To control the direction of the rotation Arduino pin 8 is used in active low configuration. A second motor is used as generator which is coupled to the motor. The output of the generator is used for feedback operation. A PID controller is used to maintain the desired output voltage level. The whole system is implemented in Matlab Simulink environment in hardware in the loop configuration. The PID controller co-efficients are tuned to get stable output voltage level from generator. A typical response of the system is shown below (reference 4 volt). As can be seen from the graph the output voltage level oscillates between 3.5 to 4.4 volt. That is PID co-efficients are not well tuned and more stable output voltage can be obtained by tuning PID co-efficients. For this project, a PID controller with $K_p = 10$, $K_i = 6$ and $K_d = 0$ is used. The controller mainly controls the duty cycle of the PWM generated by Arduino, which is then fed to the MOSFET driver and the MOSFETS are drived in our desired direction. However, the system maintains a moderate output voltage level and response is almost instantaneously. Hence, the project is successful and all the outcomes are achieved.

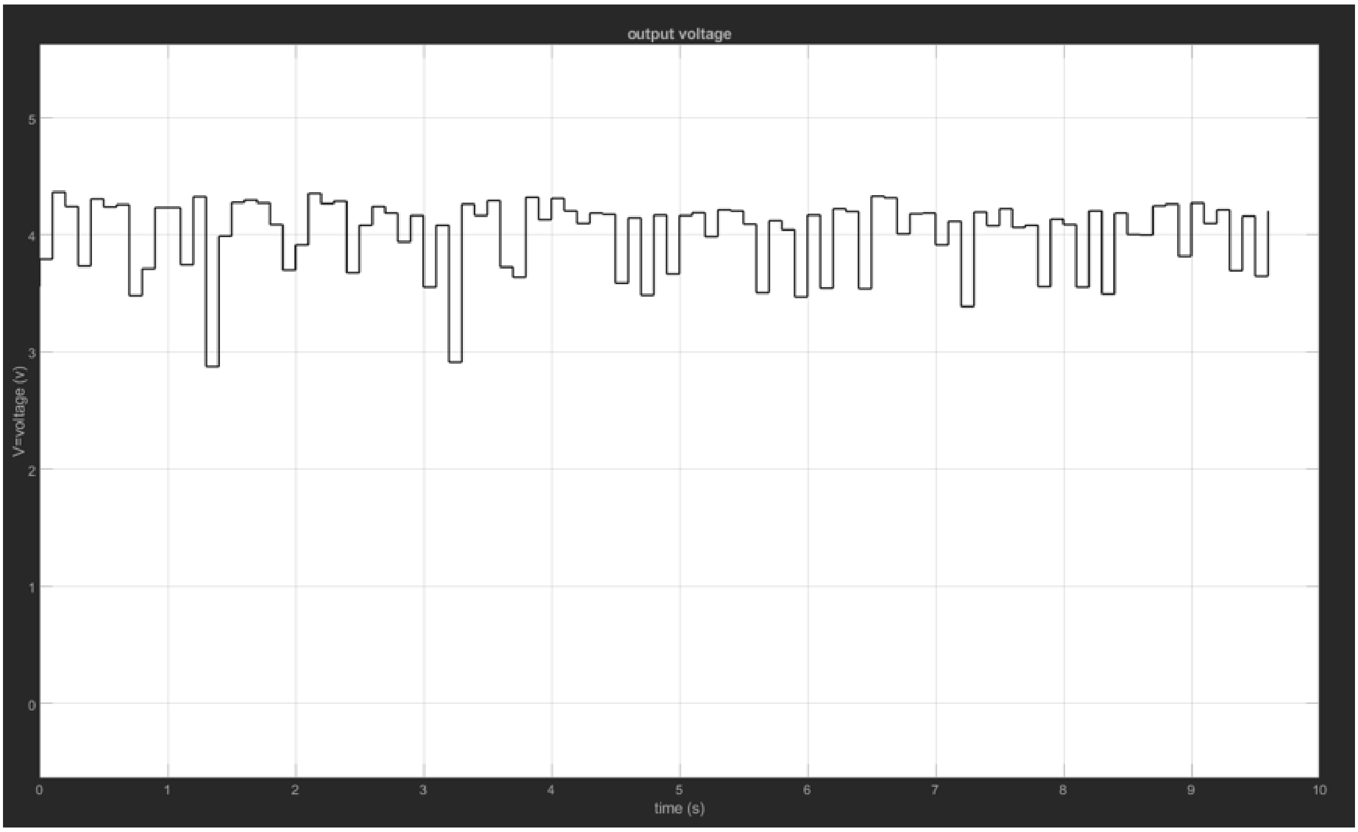

Fig 11: Response of the system when command for constant 4 Volts generation is given.

CONCLUSION:

The main purpose of this project was to build a closed loop speed controller of a prime mover for generating constant voltage. In this project, we have built a DC drive system. Then we have built a H-bridge converter with required components. We have also controlled the speed of the prime mover by using Arduino’s PWM. Lastly, we have generated constant voltage by using the voltage divider circuit. So, we can conclude that the objectives of this project have been accomplished.

REFERENCES:

[1] EE4110 project guideline

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[3] https://www.mathworks.com/help/matlab/supportpkg/code-generation-from-matlab-function-block.html