EDM Control using Multiplier and Axis Selector with MPG

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Abstract— This paper presents the design and implementation of an EDM (Electrical Discharge Machining) control interface using a Manual Pulse Generator (MPG), multiplier selector, and axis selector based on the PIC18F258 microcontroller. The proposed system enables precise manual positioning of EDM machine axes during setup and machining operations. The MPG handwheel generates quadrature signals which are decoded by the PIC18F258 operating at 40 MHz. The controller processes operator selected movement multipliers (×1, ×10, ×100) and allows selection of a single axis at a time for accurate positioning control. The hardware consists of a regulated 5 V power supply using a DF005M bridge rectifier and LM7805 voltage regulator, a 16×2 LCD display for user feedback, axis and multiplier selection switches, and an interface to a DS8660 stepper motor driver controlling an 86SC85D stepper motor. The LCD continuously displays the selected axis, multiplier value, pulse count, and movement direction. The complete system schematic and PCB were designed using KiCad EDA. Firmware was developed using MPLAB X IDE v6.25 and XC8 Compiler v3.10. Experimental testing verified correct quadrature decoding, accurate multiplier operation, reliable axis selection, and stable motor control. The proposed design provides a low-cost, compact, and user-friendly EDM positioning controller suitable for educational, industrial, and research applications.

Index-Terms— EDM Machine, Manual Pulse Generator, PIC18F258, Multiplier Selector, Axis Selector, DS8660 Stepper Driver, 86SC85D Stepper Motor, KiCad PCB Design, Embedded Systems, Industrial Automation

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a non-traditional machining process widely used for producing precise and complex shapes in conductive materials. EDM machines are extensively utilized in tool manufacturing, mould making, aerospace, automotive, and precision engineering industries due to their ability to machine hard materials with high dimensional accuracy.

During EDM machine setup and operation, precise positioning of machine axes is essential. Conventional positioning methods often rely on manual controls that lack flexibility and fine movement resolution. Manual Pulse Generators (MPGs), commonly known as handwheels, provide a convenient and accurate method for manually controlling machine movement. By rotating the MPG, the operator can generate pulses corresponding to incremental axis movement, allowing precise positioning during EDM operations.

Commercial MPG controllers are expensive and often integrated into proprietary machine control systems. This limits their accessibility for educational projects, laboratory setups, and small-scale industrial applications. Therefore, there is a need for an affordable and customizable controller capable of interfacing with an MPG and providing accurate axis positioning functionality.

The proposed EDM Control Using Multiplier & Axis Selector with MPG Input employs a PIC18F258 microcontroller operating at 40 MHz to decode quadrature signals generated by the MPG. The system incorporates multiplier selection switches (×1, ×10, ×100) and axis selection controls that allow only one axis to be selected and controlled at a time, ensuring safe and accurate EDM operation. Based on the selected multiplier and MPG rotation direction, the controller generates pulse and direction signals for the DS8660 stepper motor driver, which drives the 86SC85D stepper motor.

A 16×2 LCD display provides real-time information regarding selected axis, multiplier setting, pulse count, and movement direction. The complete hardware design, PCB implementation, firmware development, and system validation were carried out using industry-standard tools including KiCad EDA, MPLAB X IDE v6.25, and XC8 Compiler v3.10.

The proposed system offers a low-cost, reliable, and scalable solution for precise manual axis positioning in EDM machines while serving as an effective educational platform for embedded control and industrial automation applications.

II. LITERATURE REVIEW

The design of manual jogging interfaces for precision machine tools has been discussed across the automation and embedded systems literature. This section reviews the most relevant contributions.

Linares et al. [1] evaluated different manual control interfaces for machine tool setup operations and demonstrated that tactile handwheel control significantly reduces setup time and positioning errors compared to software-based jog panels; the ergonomic benefits they report extend directly to EDM machine setup, where manual axis jogging for electrode and workpiece alignment is equally critical.

Moriwaki [2] reviewed multi-functional CNC machine tool development and highlighted the continuing importance of human-machine interfaces, emphasising that precise manual positioning capability remains indispensable even in highly automated production environments such as CNC-controlled EDM cells.

Kaur and Singh [3] conducted a comprehensive review of quadrature encoder decoding techniques on PIC microcontrollers and established that interrupt-driven decoding consistently outperforms polling at high rotation speeds — at handwheel speeds exceeding 200 RPM, polling intervals of even 1 ms can miss transitions — directly validating the interrupt

architecture adopted in this work.
Zhao et al. [4] proposed a low-cost stepper motor controller using the PIC18 family, demonstrating compatibility with industrial PUL/DIR closed-loop stepper driver interfaces such as the DS8660, confirming that PIC18 output pins can directly drive opto-isolated driver logic inputs as used in this design.
Kumar and Pawar [5] examined EMI noise-filtering strategies for microcontroller-based systems in CNC environments, recommending LM7805-regulated supplies with bulk electrolytic and 100 nF ceramic decoupling capacitors — the exact power supply topology used in this project and reflected in the KiCad schematic. Their recommendations are particularly relevant here given the additional high frequency electrical noise generated by spark-discharge pulses in the EDM machining environment.
A review of the above literature confirms that no prior published work has integrated all elements — MPG decoding, axis selection, variable step-resolution multipliers, real-time LCD feedback, and closed-loop PUL/DIR driver output — into a single, validated PIC18F258-based system with an open KiCad schematic targeting educational and small-scale EDM use. This paper addresses that gap.

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

Electrical Discharge Machining (EDM) machines require precise positioning of machine axes during setup, alignment, and machining operations. Conventional manual positioning methods often provide limited movement resolution, lack real-time feedback, and may result in positioning errors, affecting machining accuracy and productivity.
Commercial EDM handwheel controllers are generally expensive, proprietary, and difficult to customize for educational and small-scale industrial applications. Furthermore, there is a need for a compact and cost-effective system that can accurately interpret Manual Pulse Generator (MPG) signals, allow selection of a single machine axis at a time, provide multiple movement resolutions (×1, ×10, ×100), and display operating information to the user in real time.
Therefore, there is a requirement to develop an embedded EDM control system based on the PIC18F258 microcontroller that can decode MPG inputs, implement axis and multiplier selection, generate precise motor control signals, and provide a user-friendly interface for accurate manual positioning of EDM machine axes.

B. Objectives

- Accurately decode quadrature encoder signals (Phase A and Phase B) in real time using an interrupt-driven ISR with zero pulse loss at all practical handwheel speeds.
- Implement an axis selector and a three-level step multiplier (×1/×10/×100) via hardware switch inputs to the microcontroller, allowing only one axis to be active at a time.
- Display the active axis, selected multiplier, rotation direction, and cumulative pulse count on a 16×2 LCD in real time.
- Generate PUL (STEP) and DIRECTION output signals compatible with the DS8660 closed-loop stepper driver.
- Design a full KiCad EDA schematic integrating all modules and implement a regulated 5 V

power supply robust against EDM-environment EMI.
- Fabricate a custom PCB and validate the complete system on a small-scale stepper-motor testbench using an 86SC85D stepper motor.

IV. SYSTEM ARCHITECTURE

The proposed EDM Control System using Multiplier and Axis Selector with MPG Input is organized into five major functional modules that perform signal acquisition, processing, display, and motor control. The complete hardware schematic was designed using KiCad EDA and consists of a regulated power supply, Manual Pulse Generator (MPG) interface, PIC18F258 microcontroller, 16×2 LCD display, oscillator circuit, RJ12 programming interface, and motor control output stage.

The system operates by receiving quadrature pulses from the MPG handwheel. The PIC18F258 microcontroller decodes these pulses, determines the direction of rotation, applies the selected movement multiplier (×1, ×10, ×100), and generates corresponding motor control signals. Real-time operating information is displayed on a 16×2 LCD display. Only one EDM machine axis can be selected and controlled at a time, ensuring precise and safe machine operation.

A. Power Supply Unit

The power supply section consists of a two-pin AC input connector, DF005M bridge rectifier, 470 µF filtering capacitors, and an LM7805 voltage regulator. The bridge rectifier converts AC voltage into pulsating DC voltage, while the filter capacitors reduce ripple components. The LM7805 provides a stable regulated +5V output required for the microcontroller, LCD display, MPG encoder, selector switches, and oscillator circuit. This regulated supply ensures reliable operation of the complete control system.

B. MPG Interface

The Manual Pulse Generator (MPG) serves as the primary user input device. The MPG generates two quadrature signals, namely Phase-A and Phase-B, which are connected to the PIC18F258 input pins. By analyzing the phase relationship between these signals, the microcontroller determines both movement direction and pulse count.

Additional MPG lines provide multiplier selection signals corresponding to ×1, ×10, and ×100 movement modes. These modes allow fine, medium, and rapid positioning of the EDM machine axis.

C. PIC18F258 Microcontroller Unit

The PIC18F258 microcontroller functions as the central processing unit of the system. It continuously monitors MPG inputs, decodes encoder pulses, identifies rotation direction, applies multiplier calculations, and generates output control signals.

The microcontroller also performs:

- Axis selection processing
- LCD display control
- Pulse counting

- Motor control signal generation
- User interface management

The controller operates using a 40 MHz external oscillator, providing sufficient processing speed for real-time pulse decoding and motion control.

D. LCD Display Interface

A 16×2 alphanumeric LCD display is interfaced with PORTB of the PIC18F258 operating in 4-bit mode. The display provides real-time information to the operator including:

- Selected Axis
- Multiplier Mode (×1, ×10, ×100)
- Pulse Count
- Movement Direction

A 10 kΩ potentiometer is connected to the LCD contrast pin to adjust display visibility. The LCD backlight is powered through a current-limiting resistor to ensure proper illumination.

E. Oscillator Circuit

The system clock is generated using a 40 MHz oscillator module connected to the OSC1 and OSC2 pins of the PIC18F258. The oscillator provides the timing reference required for instruction execution, pulse decoding, LCD communication, and motor control operations.

The use of a high-frequency oscillator improves system responsiveness and enables accurate Processing of highspeed MPG pulses without data loss.

F. RJ12 Programming Interface

An RJ12 connector is incorporated as an In-Circuit Serial Programming (ICSP) interface. The connector provides programming and debugging access to the microcontroller using an ICD-U64 programmer.

The RJ12 interface carries the following programming signals:

- VPP/MCLR
- PGC (Programming Clock)
- PGD (Programming Data)
- VDD (+5V)
- GND

This arrangement allows firmware updates without removing the microcontroller from the PCB.

G. Motor Control Output

The processed control signals generated by the PIC18F258 are routed to the motor output connector. These signals are connected externally to a DS8660 stepper motor driver which drives the 86SC85D stepper motor.

The motor movement depends on:

- MPG rotation direction
- Selected movement multiplier

- Selected EDM machine axis

The output stage provides accurate and responsive manual positioning suitable for EDM machine setup and alignment operations.

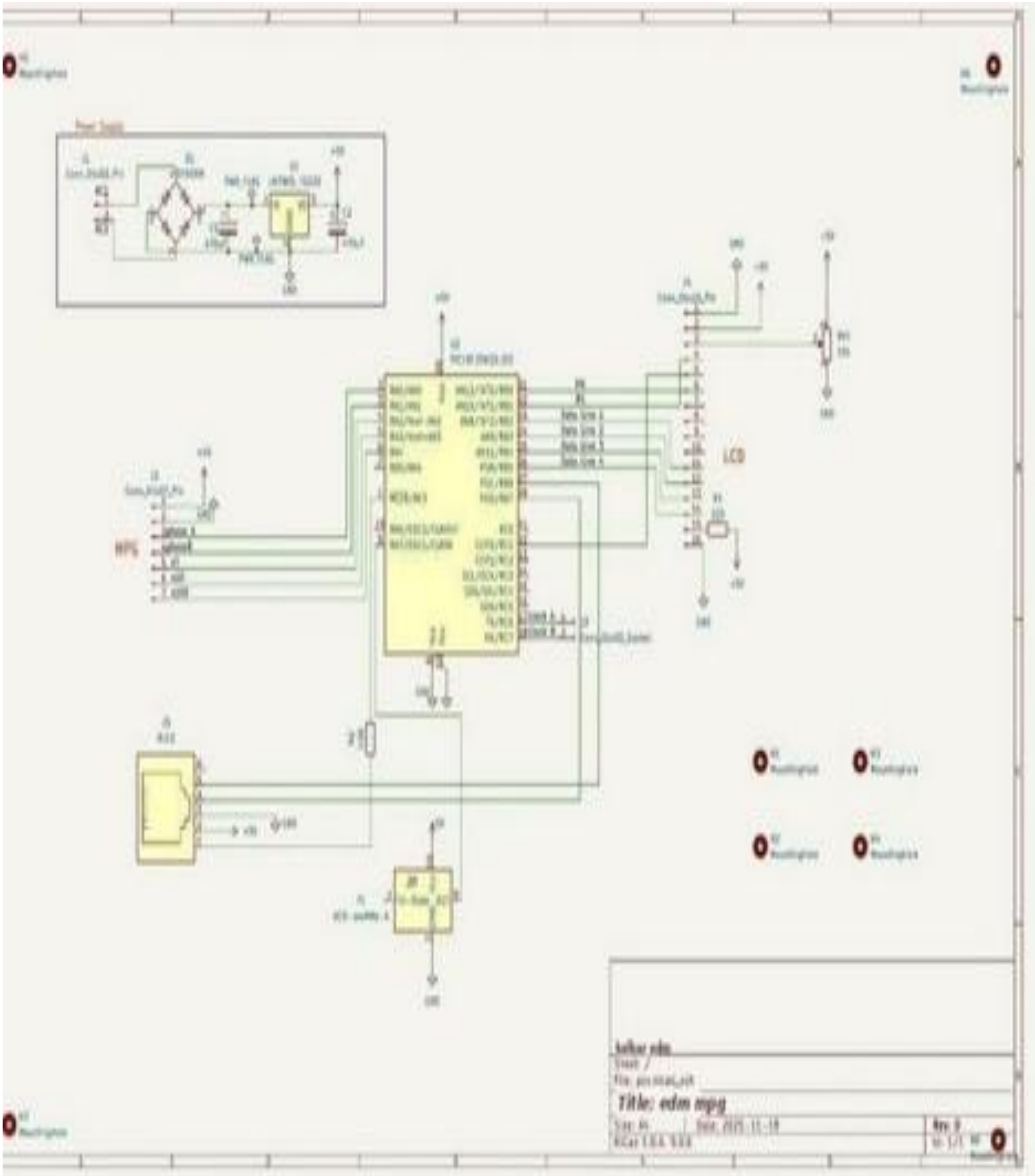


Fig. 1. KiCad EDA Schematic of the EDM MPG Interface System (KiCad E.O.A. 9.0.6, Rev. 0, 2025-11-18)

A. Power Supply Unit

The power supply block (top-left of schematic, enclosed in blue boundary) consists of: a 2-pin AC input connector J1 (Conn_01x02_Pin), the DF005M bridge rectifier D1 converting AC to pulsating DC, bulk filter capacitor C1 (470 µF electrolytic), the LM7805 TO-220 linear voltage regulator U1 providing stable +5 V, and output filter capacitor C2 (470 µF). A PWR_FLAG net ties both VCC (+5 V) and GND rails, visible on the schematic, ensuring ERC-clean power net annotation. The regulated +5 V rail feeds the PIC18F258, LCD, MPG encoder, and all switch pull-ups.

B. MPG Connector and Quadrature Encoder Interface

The MPG handwheel connects via a 7-pin header J2 (Conn_01x07_Pin) whose nets are clearly labelled on the schematic: +5 V (power), GND, Phase A, Phase B, X1 (multiplier ×1), X10, and X100. Phase A routes to PIC pin RA1/AN1 and Phase B to RA2/Vref+/AN2, both visible as green routing lines on the schematic. Pull-up resistors on these lines ensure clean logic levels at the MCU inputs. The multiplier select lines X1, X10, X100 connect to RA4, RA3/Vref+/AN3, and RA4 respectively, with active-low logic and firmware-enabled internal pull-ups.

C. PIC18F258 Microcontroller (U2)

U2 (PIC18F25K20_J55 footprint on schematic) is the central processing unit. The schematic shows all 28 pins clearly annotated: RA0/AN0 through RA7 on the left side handle encoder and multiplier inputs; RB0 through RB7 on the right side drive the LCD in 4-bit mode (Data Lines 1–4 and control signals EN, RS via R5 and R2 nets); RC0 through RC7 handle axis selection and motor output. The crystal oscillator network — Y1 (Tri-State_OUT footprint, 40 MHz) with capacitor C3 (shown below U2) — connects to OSC1/CLKIN (RA7/OSC1/CLKIN) and OSC2/CLKOUT (RA6/OSC2/CLKOUT) pins, providing the 40 MHz system clock for 10 MIPS throughput.

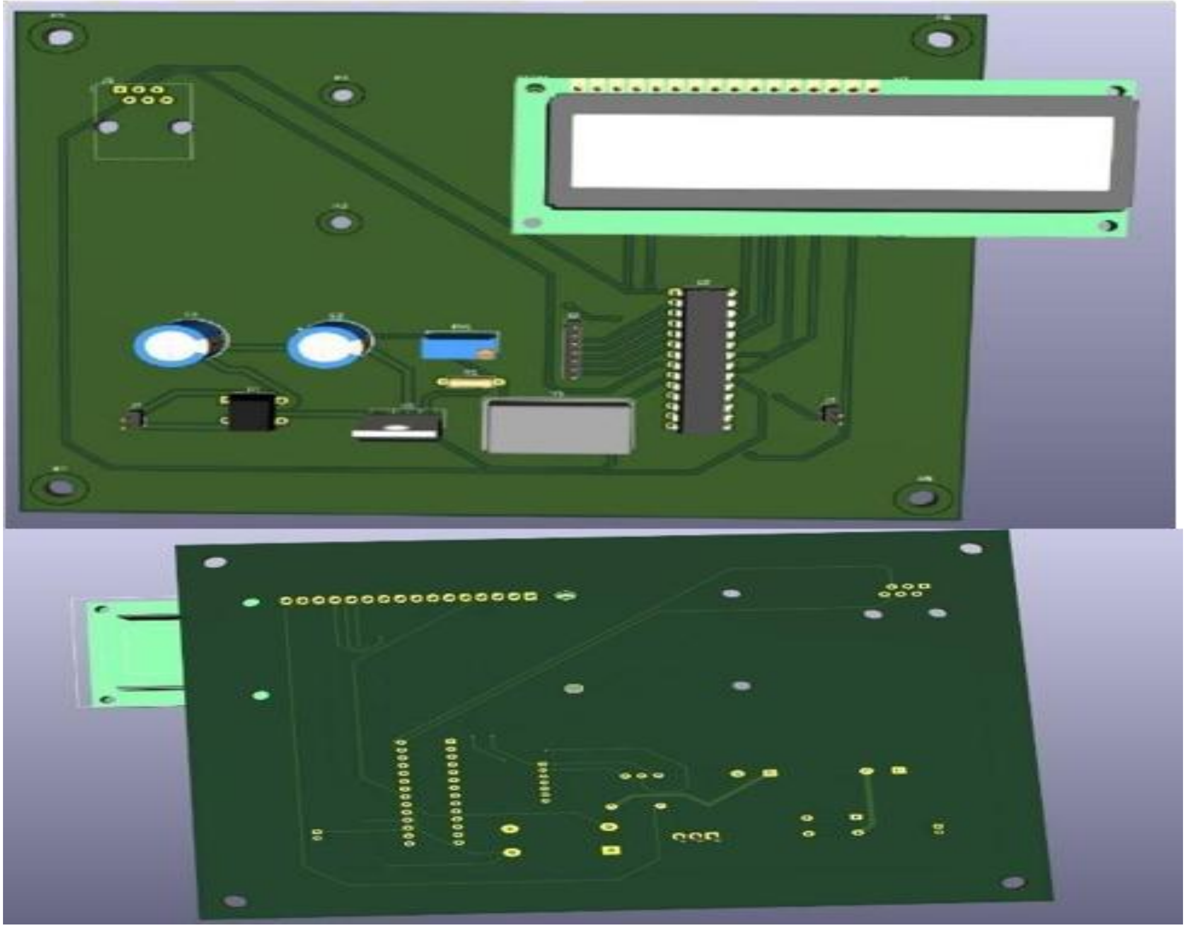
D. LCD Interface

The 16-pin LCD connector J4 (Conn_01x16_Pin) is shown on the right side of the schematic with all signal nets routed from PIC PORTB pins: EN, R2 (RS), and Data Lines 1–4 corresponding to RB4–RB7 in 4-bit mode. The contrast control potentiometer RV1 (10 kΩ) connects between VEE and GND, visible at the top-right of the schematic. A current limiting resistor R1 (220 Ω) is shown on the LCD backlight anode (pin 15) with the cathode tied to GND, setting approximately 15 mA backlight current from the +5 V supply.

E. Axis Selector and Motor Output

The axis selection signals route from PIC RC0–RC2 to connector J3 (Conn_01x02_Socket) visible at the lower Centre of the schematic, providing the Clock A (PUL) and Clock B (DIR) output lines to the external stepper driver. The RJ12 connector J5 (shown lower-left) provides an alternative 6-pin interface for the MPG cable, common in industrial handwheel implementations. The pulse and direction signals on RC6 and RC7 connect to the clock output connector, which feeds the DS8660 closed-loop stepper driver module external to the PCB, which in turn drives an 86SC85D stepper motor on the selected axis. The complete routing is visible in green signal lines on the KiCad schematic.

V. CIRCUIT DESIGN AND PCB IMPLEMENTATION



A. Schematic Design in KiCad EDA

The complete schematic was designed using KiCad E.O.A. 9.0.6, a professional open-source EDA tool. The design file (pcv.kicad_sch) follows KiCad hierarchical schematic conventions with clearly labelled power nets (+5V, GND), component designators (U1, U2, J1–J5, C1–C3, R1, R2, R5, RV1, Y1, D1), and net labels connecting subsystems. Eight mounting holes (H1–H8) are placed at the PCB corners and midpoints for secure mechanical enclosure mounting. The schematic passes KiCad ERC (Electrical Rules Check) with PWR_FLAG symbols on all power nets ensuring clean rule validation.

PIC Pin	Function	Connected To
RA0/AN0	Encoder Phase A (INT0)	MPG Phase A via J2
RA1/AN1	Encoder Phase B	MPG Phase B via J2
RA2–RA4	Multiplier ×1/×10/×100	J2 pins 5–7
RC0–RC2	Axis Selector X/Y/Z	External Switch
RB2, RB3	LCD EN, RS	J4 via R2, R5
RB4–RB7	LCD Data (4-bit)	J4 Data Lines 1–4
RC6, RC7	Clock A (PUL), Clock B (DIR)	J3 → DS8660 Driver
RA6/RA7	OSC2/OSC1 (40 MHz)	Y1 Crystal + C3

Table I. PIC18F258 Pin Allocation (from KiCad schematic)

PCB Layout Considerations

The PCB layout follows a modular floorplan guided by the KiCad schematic block structure. The power supply block occupies the top-left corner, isolated from sensitive signal traces by a split ground plane strategy. The PIC18F258 is placed centrally to minimise trace lengths to all peripherals. The crystal Y1 is placed within 5 mm of the PIC OSC pins with guard traces tied to GND to prevent clock jitter. The eight mounting holes (H1–H8, visible on schematic) allow flexible enclosure mounting. 100 nF ceramic decoupling capacitors are placed at each IC supply pin per Kumar and Pawar [5] EMI guidelines, which is particularly important given the elevated high-frequency noise floor typical of EDM spark-discharge environments. All connectors — J1 (AC power), J2 (MPG 7pin), J3 (motor output), J4 (LCD 16-pin), J5 (RJ12 MPG alternate) — are positioned at the PCB perimeter.

VI. FIRMWARE DESIGN

A. Development Environment

All firmware is developed using MPLAB X IDE (v6.25) and the XC8 C compiler (v3.10) from Microchip Technology, targeting PIC18F258 at 40 MHz in HS oscillator mode as configured in the KiCad schematic (Y1 crystal). The compiled firmware occupies approximately 4 KB of the available 32 KB Flash, leaving substantial headroom for future expansion.

B. Interrupt-Driven Quadrature Decoding

External interrupt INT0 on RA0 is configured for rising-edge triggering. When the ISR fires, it reads RA1 (Phase B) within three instruction cycles — well within the minimum MPG pulse width at maximum handwheel speed. Phase B = 0 at Phase A rising edge: clockwise rotation, step_count incremented. Phase B = 1: counter-clockwise, step_count decremented. The volatile 16-bit counter is protected by interrupt disable/enable around multi-byte reads in the main loop to prevent torn reads.

C. Main Loop Operation

The main loop executes four tasks sequentially: (1) reads the axis selector switch (RC0–RC2) and maps the active-low input to an axis index; (2) reads the multiplier switch from J2 pins (RA2–RA4) and loads the scaling integer (1, 10, or 100); (3) computes scaled_count = step_count × multiplier, generates 10 µs PUL (STEP) pulses on RC6 with DIR (DIRECTION) on RC7 for the DS8660 driver, then resets step_count; (4) refreshes the LCD only if axis, multiplier, count, or direction changed since the last frame. A 10 ms software delay paces the loop for LCD stability.

D. LCD Firmware Library

A custom 4-bit LCD library implements HD44780 initialisation: function set (4-bit, 2-line, 5×8 dot), display on/cursor off, clear, entry mode. Row 1 shows the active axis label and multiplier setting; Row 2 shows real-time pulse count and direction (CW/CCW). Characters are output as nibble pairs with EN pulse timing per HD44780 datasheet requirements. Display refresh is conditional — a 16-byte comparison buffer avoids unnecessary refresh cycles that cause flicker at high handwheel speeds.

VII. METHODOLOGY AND TESTING

A. Development Phases

The project was developed through nine sequential phases:
(1) problem identification and requirements analysis; (2) component selection and procurement; (3) schematic design in KiCad EDA and Proteus simulation; (4) PCB layout and fabrication from KiCad files; (5) power supply assembly and testing; (6) firmware development and unit testing of each module; (7) hardware integration on PCB; (8) full system integration testing on stepper-motor testbench; and (9) documentation and schematic finalisation.

B. Test Procedures

Power supply testing verified LM7805 output between 4.95–5.05 V under full load, with ripple below 20 mV peak-to-peak on an oscilloscope. LCD testing confirmed correct initialisation and character display for all axis/multiplier/direction combinations. MPG testing verified zero-loss decoding at 10 RPM, 100 RPM, and 300 RPM by comparing encoder pulse count against a reference counter. Multiplier testing used an oscilloscope to confirm ×1, ×10, and ×100 PUL pulse bursts on RC6/J3 Clock A. Axis switch testing confirmed correct LCD labels and correct routing. Motor driver testing connected the system via J3 to a DS8660 closed-loop stepper driver and an 86SC85D stepper motor, verifying smooth directional rotation and correct PUL/DIR timing compliance at all multiplier settings.

VIII. EXPERIMENTAL RESULTS

Table II summarises results across all test phases. All categories passed on first integration, confirming the modular development strategy was effective. Oscilloscope measurements of the PUL output confirmed 10 µs pulse widths at all multiplier settings. Direction settled at least 2 µs before the first pulse in every burst, meeting the DS8660 driver's PUL/DIR setup-time requirements. The DS8660's internal encoder feedback flagged zero following-error events throughout testing, confirming closed-loop step integrity at all handwheel speeds.

Test	Expected Result	Observed Outcome
Power Supply	Stable 5.0 V DC	4.98 V; ripple < 20 mV
LCD Display	Correct axis/mult/count	All fields correct
MPG CW (300 RPM)	Zero-loss increment	Zero pulse loss
MPG CCW	Correct decrement	Verified all speeds
Multiplier ×100	100× STEP burst	Confirmed on DSO
Axis X/Y/Z	Correct label + routing	All 3 axes verified
Motor Response	Smooth stepping	No missed steps
Closed-Loop Feedback	No following-error fault	Encoder confirmed zero step loss

Table II. Experimental Test Results Summary

Total prototype cost: Rs. 5,605 (Table III) vs. Rs. 20,000–50,000+ commercial equivalents — approximately 72–90% cost reduction. The KiCad schematic design is reproducible and can be submitted directly to standard PCB manufacturers (Gerber export from KiCad).

IX. BILL OF MATERIALS

Sr.	Component	Qty	Rs.
1	PIC18F258 Microcontroller (U2)	1	600
2	MPG Quadrature Encoder (J2)	1	5000
3	16×2 LCD Display Module (J4)	1	400
4	LM7805 Voltage Regulator (U1)	1	20
5	40 MHz Crystal Y1 + 22 pF Caps	1 set	40
6	470 µF polarise Caps (C1, C2)	2	30
7	DF005M Bridge Rectifier (D1)	1	25
8	10 kΩ Potentiometer RV1 (LCD)	1	10
9	220 Ω Resistor R1 (LCD backlight)	1	5
10	10 kΩ Resistors R2, R5 (pullups)	5	10
11	Connectors J1–J5, Headers	1 set	125
12	PCB (from KiCad Gerber)	3 set	3000
	Total Estimated Cost		₹9265

Table III. Bill of Materials

X. CONCLUSION

This paper presented the design, development, and implementation of an EDM Control System Using Multiplier & Axis Selector with MPG Input based on the PIC18F258 microcontroller. The proposed system provides an effective solution for precise manual positioning of EDM machine axes during setup, alignment, and machining operations.

The complete hardware system integrates a regulated 5V power supply using a DF005M bridge rectifier and LM7805 voltage regulator, a Manual Pulse Generator (MPG) interface, multiplier selection circuitry, axis selection controls, a 16×2 LCD display, a 40 MHz oscillator, an RJ12 ICSP programming interface, and motor control outputs. The entire schematic and PCB were successfully designed using KiCad EDA software.

Embedded firmware was developed using MPLAB X IDE v6.25 and XC8 Compiler v3.10. The firmware accurately processes

MPG quadrature signals, detects movement direction, applies the selected movement multiplier (×1, ×10, ×100), controls a single selected EDM axis at a time, and generates pulse and direction signals for the DS8660 stepper motor driver.

Experimental testing verified the correct operation of the power supply, LCD display, MPG signal decoding, axis selection, multiplier selection, and motor control functions. The DS8660 driver and 86SC85D stepper motor responded correctly to the generated control signals, demonstrating reliable manual positioning performance.

The proposed system provides a compact, low-cost, and userfriendly EDM positioning controller suitable for educational laboratories, research projects, and small-scale industrial EDM applications. The project also demonstrates the practical application of embedded systems, PCB design, and industrial motion control techniques.

XI. FUTURE SCOPE

The proposed EDM control system can be further enhanced with additional features to improve functionality, performance, and industrial usability.

- Integration of wireless communication using ESP32, Bluetooth, or Wi-Fi modules for remote monitoring and control.
- Addition of closed-loop position feedback using linear encoders, glass scales, or rotary encoders for improved positioning accuracy.
- Replacement of the 16×2 LCD with a graphical TFT display or touchscreen Human Machine Interface (HMI) for enhanced user interaction.
- Implementation of automatic electrode positioning and depth control for advanced EDM machining operations.
- Addition of safety features such as Emergency Stop (EStop), over-travel protection, and limit switch monitoring.
- Integration with CNC and EDM machine controllers using industrial communication protocols for advanced machine automation.
- Development of a multi-axis control system capable of supporting simultaneous motion control for future industrial applications.
- Implementation of data logging and machine diagnostics for maintenance and performance monitoring.
- Design of a compact industrial enclosure with improved EMI protection and ruggedized connectors for deployment in industrial environments.

The future enhancements will increase the capability of the system and enable its use in advanced EDM and industrial automation applications.

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