Industrial Grade VMC Controller – Full Design & Schematic Roadmap

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Target: 12x12 DC Motor Matrix | 24V / 12V Industrial Vending Machine Controller

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1. System Architecture Overview

High-Level Block Diagram (Text)

```
24V IN
  |
[Protection & EMI]
  |
[DC/DC 24→5V] ----> [LDO/DC 5→3.3V]
  |
+5V Rail --------------------------+
                                   |
                             +-----+-----+
                             |   ESP32    |
                             +-----+-----+
                                   |
         +-------------------------+-----------------------+
         |                         |                       |
   Shift Registers         ADC System            IO Expander
  SN74HC595 x3        MCP3208 x2          MCP23017 (I2C)
         |                         |                       |
   ULN2803 Drivers      Motor Feedback        Sensors / PCB-B ID
         |
   FDS4897 MOSFET Matrix
         |
     Motors via PCB-B (Card Edge)
```

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2. PCB Stack Strategy

PCB	Purpose	Notes
PCB-A	Master Controller	Power, MCU, Drivers, ADC, Shift Reg, Protection
PCB-B	Machine Adapter	Motor connectors, Sensors, Fans, Relays, ID Resistors

Connector

64-Pin Card Edge / X2549WR-2x32A-PTV10

PCB Thickness

Board	Thickness	Reason
PCB-A	1.6mm	Standard industrial, good rigidity
PCB-B	1.6mm ENIG edge	Reliable card edge contact

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3. Power Section (Industrial Grade)

This is the **foundation of the entire VMC system**. If this block is noisy or unstable, motors will reset ESP32, ADC will misread, and feedback will fail. Build and test this section first on PCB-A.

3.1 Power Flow (Functional Chain)

```
24V_DC_INPUT
   |
[F1 Polyfuse]
   |
[Reverse Polarity Protection]
   |
[TVS Surge Clamp]
   |
[EMI LC Filter]
   |
[Bulk Capacitor Bank]
   |
[24V → 5V Buck Converter]
   |
[5V Ferrite Split]
   +--------------------+
   |                    |
[5V Digital Rail]   [5V Analog Rail]
   |                    |
[LDO 3.3V]        [ADC / Comparator]
```

3.2 Connector & Entry Stage

DC Input Connector (PCB-A)

Ref	Part	Spec	Why
J1	Screw Terminal	5.08mm, 10A	Industrial wiring

Protection Components

Ref	Component	Value	Placement Rule	Why
F1	Polyfuse	5A–7A Hold	First part after J1	Short & overload protection
D1	TVS Diode	SMBJ33A	Across 24V-GND	Absorbs surges
D2	Reverse MOSFET	AO4407 / IRLML6402	Series	No voltage drop vs diode

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3.3 EMI Filter Network

Industrial Input Filter

```
24V_IN ── FB1 ──+── FB2 ── 24V_FILTERED
                |
               C1
                |
               GND
```

Ref	Part	Value	Why
FB1	Ferrite Bead	120Ω @100MHz	Blocks HF noise
FB2	Ferrite Bead	120Ω @100MHz	Second stage
C1	Ceramic	100nF	High-frequency bypass
C2	Electrolytic	470uF / 50V	Bulk energy

Placement: Within **20mm of J1**

3.4 24V → 5V Buck Converter

Recommended IC

IC	Rating	Why
MP1584	3A	Compact, efficient
LM2596	3A	Proven industrial

Standard Buck Schematic

```
24V_FILTERED
   |
  CIN (100uF + 100nF)
   |
[BUCK IC]── L1 ──+── 5V_OUT
```

```
                  |
                 COUT
                  |
                 GND
```

Component Table

Ref	Part	Value	Rule
CIN1	Electrolytic	100uF 50V	Close to VIN
CIN2	Ceramic	100nF	Parallel to CIN1
L1	Inductor	33µH / 4A	Low DCR
D3	Schottky	SS54	Flyback
COUT1	Electrolytic	470uF 10V	Bulk load
COUT2	Ceramic	1uF	Noise

3.5 5V Rail Splitting

This prevents motors and ULN noise from corrupting ADC and ESP32.

```
5V_MAIN
   |
  FB3
   +--------- 5V_DIGITAL
   |
  FB4
   +--------- 5V_ANALOG
```

Ref	Value	Why
FB3, FB4	120Ω Ferrite	Noise isolation

3.6 5V → 3.3V Regulation

Recommended

Part	Current	Why
AP2112	600mA	Low noise
TLV1117	800mA	Robust

LDO Circuit

```
5V_DIGITAL
    |
  C10 (10uF)
    |
 [LDO]── 3.3V_OUT
    |
  C11 (10uF)
    |
  GND
```

Ref	Value
C10	10uF
C11	10uF
C12	100nF

3.7 Ground Strategy

Star Ground Zones

```
GND_MOTOR
    |
 [Single Point]
    |
GND_POWER
    |
GND_DIGITAL
    |
GND_ANALOG
```

Zone	Used For
GND_MOTOR	MOSFETs, motors
GND_ANALOG	MCP3208, LM393
GND_DIGITAL	ESP32, logic

Join ONLY at **DC input negative**

3.8 Test Points (Must Add)

Ref	Net	Why
TP1	24V_IN	Input health
TP2	24V_FILTERED	EMI stage
TP3	5V_MAIN	Buck output
TP4	5V_ANALOG	ADC rail
TP5	3.3V	MCU rail
TP6	GND	Scope reference

3.9 PCB Layout Rules (Power Section)

Rule	Value	Why
24V Trace Width	4–6mm	6A safe
Buck Loop Area	Minimum	EMI
GND Plane	Solid L2	Noise return
Clearance 24V	≥1.2mm	Safety
Copper	2oz	Thermal

3.10 Validation Checklist

Test	Expected
No-load 5V	5.05–5.15V
No-load 3.3V	3.28–3.35V
Load Step	<200mV dip
TVS Test	No reset on surge

3.11 EasyEDA Drawing Order

1. Place J1, F1, TVS, Reverse MOSFET
2. Draw EMI Filter
3. Draw Buck Converter
4. Split 5V Rails
5. Draw LDO
6. Add Test Points
7. Assign Net Labels

This block alone makes your design **industrial, not hobby-grade**.

4. ESP32 + Digital Domain Schematic (Industrial Grade)

This section is the **brain of your VMC**. It must survive motor noise, ESD from operators, long cables, and power dips without crashing or entering bootloader mode.

4.1 Power & Reset Architecture

Power Flow

```
3.3V_DIGITAL
   |
 FB5 (Ferrite)
   |
ESP32_3V3
```

Ref	Part	Value	Why
FB5	Ferrite Bead	120Ω @100MHz	Isolate MCU noise
C101	Ceramic	100nF	Local decoupling
C102	Ceramic	1uF	Local bulk
C103	Tantalum/Elec	10uF	Load stability

Place all three capacitors within **5mm of ESP32 VDD pins**

4.2 Boot & Enable Circuit (Critical)

ESP32 will randomly fail if EN/BOOT pins float or get motor noise.

Standard Industrial Circuit

```
3.3V
 |
 R_EN (10k)
 |
EN ──── C_EN (1uF) ── GND

GPIO0 (BOOT)
 |
 R_BOOT (10k)
 |
3.3V
```

Ref	Value	Why
R_EN	10k	Pull-up
C_EN	1uF	Noise filter
R_BOOT	10k	Normal boot

4.3 Programming & Debug Header

Header

Ref	Part
J2	1x6 2.54mm

Pin Mapping

J2 Pin	Net
1	3.3V
2	GND
3	EN
4	GPIO0
5	UART_TX
6	UART_RX

4.4 UART + MAX3232 Interface

Signal Flow

```
ESP32_TX → R201 → MAX3232 → DB9_PIN2
ESP32_RX ← R202 ← MAX3232 ← DB9_PIN3
```

Ref	Value	Why
R201/R202	100Ω	EMI damping
C210–C213	100nF	Charge pump

ESD Protection

Ref	Part
D201	PESD5V

4.5 I2C Bus (Shared Domain)

Devices: - MCP23017 (IO Expander) - MPU6050 (IMU) - OLED

Bus Schematic

```
3.3V
 |
 R_SDA (4.7k)
 |
SDA ----------------+----+----+
SCL ----------------+----+----+

            MCP23017 MPU6050 OLED
```

Ref	Value	Why
R_SDA	4.7k	Pull-up
R_SCL	4.7k	Pull-up

Add optional:

Ref	Part	Why
R_SER	33Ω	Edge smoothing

4.6 SPI Bus (ADC Control)

Used for MCP3208

Signal	ESP32	Protection
CLK	GPIO14	33Ω series
MOSI	GPIO13	33Ω
MISO	GPIO12	33Ω
CS	GPIO15	33Ω

4.7 Shift Register Control Lines

Net	ESP32 GPIO	Protection
DATA	GPIO5	33Ω

Net	ESP32 GPIO	Protection
CLK	GPIO18	33Ω
LATCH	GPIO19	33Ω
OE	GPIO23	33Ω

Add 100k pulldown on OE to keep motors OFF at boot

4.8 Buzzer Output

Driver

```
GPIO → R301 (1k) → NPN → Buzzer → 5V
```

Ref	Value
R301	1k
Q301	BC547 / 2N2222
D301	1N4148

4.9 ESD & IO Protection

Location	Method
External Headers	TVS Diode
MCU GPIO	33Ω Series
Long Lines	RC Filter (100Ω + 100pF)

4.10 Test Points

Ref	Net
TP10	EN
TP11	GPIO0
TP12	UART_TX
TP13	UART_RX
TP14	SDA
TP15	SCL

4.11 PCB Layout Rules (Digital Zone)

Rule	Value	Why
Ground Plane	Solid L2	Return path
Clock Lines	Short, no vias	Timing
I2C Length	<100mm	Stability
Distance to Motor Zone	>15mm	Noise

4.12 Placement Strategy

Component	Location
ESP32	Top-center
MAX3232	Board edge near DB9
I2C Devices	Clustered
Pull-ups	Near ESP32

4.13 Validation Checklist

Test	Pass Condition
Boot	No GPIO0 low
Reset	Clean restart
UART	Stable at 115200
I2C Scan	All devices found

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5. Shift Registers + ULN2803 + MOSFET Driver Domain (Industrial Power Control Layer)

This is the **industrial firewall** between your ESP32 logic and 24V / 3A motor power. If this section is designed well, your MCU will survive years in a vending machine environment.

5.1 Functional Architecture

```
ESP32
  |
SN74HC595 (x3)  →  24-bit Motor Enable Logic
```

```
  |
ULN2803 (Current Buffer + Isolation)
  |
Gate Network (100Ω + 100k)
  |
FDS4897 Dual MOSFET
  |
24V Motor Lines → PCB-B Card Edge
```

5.2 Shift Register Chain (24 Outputs)

Devices

Ref	Part	Why
U501–U503	SN74HC595N	Industrial, daisy-chainable

Daisy Chain Wiring

Signal	U501	U502	U503
SER	ESP32 DATA	Q7S U501	Q7S U502
SHCP	ESP32 CLK	Common	Common
STCP	ESP32 LATCH	Common	Common
OE	ESP32 OE	Common	Common
MR	3.3V	Common	Common

Resistors

Ref	Value	Why
R501–R524	33Ω	Signal damping
R525–R548	100k	Output pulldown

5.3 ULN2803 Buffer Stage

Purpose

- Protect shift registers
- Provide current to MOSFET gates
- Absorb inductive kick

Connection

ULN2803 Pin	Connect To
IN1–IN8	SN74HC595 Q Outputs
OUT1–OUT8	MOSFET Gate Network
COM	+24V (Flyback clamp)
GND	GND_MOTOR

Protection

Ref	Value
C510	100nF

5.4 MOSFET Power Stage

Device

Part	Rating
FDS4897	30V, 6A Dual

Gate Network (Per MOSFET)

```
ULN_OUT ── Rg (100Ω) ── GATE
                 |
                Rpd (100k)
                 |
                GND
```

Drain Protection

Ref	Part	Why
D510	SS54	Flyback diode
TVS510	SMBJ33A	Surge clamp

5.5 Motor Power Distribution

Power Bus

Parameter	Value
Copper	2oz
Width	5mm
Via	1.2mm / multiple

Decoupling Per Row

Ref	Value	Location
C520	100uF 35V	Each row feed
C521	100nF	Parallel

5.6 Safe Motor Enable Logic

Boot State

Signal	Default
OE	LOW
ULN IN	LOW
MOSFET	OFF

This ensures **NO MOTOR CAN TURN ON AT RESET OR BROWNOUT**

5.7 Test Points

Ref	Net
TP20	OE
TP21	LATCH
TP22	CLK
TP23	DATA
TP24	ROW_24V
TP25	SLOT_1

5.8 PCB Layout Rules (Power Domain)

Rule	Value	Why
Zone	Board Edge	Thermal
Clearance	≥1.2mm	24V safety
Motor Traces	5mm+	3A load
Signal to Power Gap	≥10mm	Noise

5.9 Zoning Strategy

Zone	Components
Digital	ESP32, 74HC595
Buffer	ULN2803
Power	MOSFETs, TVS, Motors

Use **physical gaps + ground stitching vias** between zones

5.10 Validation Checklist

Test	Expected
OE Low	No gate voltage
Single Bit	One motor only
Two Bits	Adjacent rows only
Surge Test	No MCU reset

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6. Motor Feedback + MCP3208 + LM393 Domain (Precision & Reliability Layer)

This block is what makes your VMC **accurate, repeatable, and professional**. It ensures every motor stops at the correct 360° position — whether feedback comes from a real sensor pin (3-pin motors) or a current-drop spike (2-pin motors).

6.1 Feedback Architecture Overview

You are supporting **two fundamentally different motor types**:

Motor Type	Feedback Method	Electronics
3-Pin Motors (SEAGA, BENCH)	Dedicated feedback wire	MCP3208 ADC
2-Pin Motors (TCN, XY)	Current-drop spike on 360° switch	LM393 Comparator

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6.2 Analog Zoning Rule (Critical)

This entire section must sit in **ANALOG ZONE**:

- Separate from MOSFETs by ≥20mm
- Ground = GND_ANALOG
- Power = 5V_ANALOG

Never allow motor traces under this block.

6.3 MCP3208 – 3-Pin Motor Feedback ADC

Device

Part	Spec
MCP3208	8ch, 12-bit SPI ADC

Power & Reference

```
5V_ANALOG ── FB601 ── VDD
                 |
               C601  100nF
                 |
               GND_ANALOG

VREF ── 4.096V REF IC or 5V_ANALOG (filtered)
```

Recommended Reference (Industrial)

Part	Why
MCP1541 (4.096V)	Stable ADC scaling

6.4 Feedback Input Network (Per Channel)

Voltage Conditioning

```
MOTOR_FB ── R1 (8.2k) ──+── ADC_CH
                        |
```

```
                      R2 (10k)
                         |
                      GND_ANALOG

ADC_CH ── C (100nF) ── GND_ANALOG
```

Part	Value	Why
R1	8.2k	Limit current
R2	10k	Scale voltage
C	100nF	Noise filter

Supports up to ~24V motor feedback safely

6.5 SPI Wiring (From ESP32)

Signal	Net	Protection
CLK	ADC_CLK	33Ω series
MOSI	ADC_DIN	33Ω
MISO	ADC_DOUT	33Ω
CS	ADC_SHDN	33Ω

6.6 2-Pin Motor Current Spike Detection

Principle

When motor cam switch opens at 360°, **current drops suddenly**. This creates a voltage spike across a shunt resistor. LM393 detects this.

6.7 Current Sense Network

Per Motor Pair (Odd / Even)

```
MOTOR_RETURN ── RSHUNT (0.1Ω / 1W) ── GND_MOTOR

Sense+ ── RC Filter ── LM393+
Sense- ────────────── LM393-
```

Part	Value	Why
RSHUNT	0.1Ω	Generates spike

Part	Value	Why
C701	10nF	Noise suppression
R701	1k	Input limit

6.8 LM393 Comparator Network

Hysteresis Design

```
5V_ANALOG
   |
 RPU (4.7k)
   |
OUT ──────→ ESP32 GPIO
   |
  RFB (100k)
   |
 +IN

-IN ── Threshold Divider
```

Part	Value	Why
RPU	4.7k	Open collector pull-up
RFB	100k	Hysteresis
RTH1	10k	Threshold set
RTH2	2.2k	Threshold set

6.9 Odd / Even Channel Split

Comparator	Motors
LM393-A	Slots 1,3,5,7,9,11
LM393-B	Slots 2,4,6,8,10,12

This allows **two motors in adjacent rows** to be detected independently.

6.10 Output Interface to ESP32

Net	GPIO	Note
FB_ODD	GPIO32	Interrupt capable

Net	GPIO	Note
FB_EVEN	GPIO33	Interrupt capable

Add:

Part	Value
R_SER	100Ω
C_FILT	100pF

6.11 Test Points

Ref	Net
TP60	ADC_VREF
TP61	FB_CH1
TP62	FB_CH8
TP63	SHUNT_ODD
TP64	SHUNT_EVEN
TP65	FB_ODD
TP66	FB_EVEN

6.12 PCB Layout Rules (Analog Zone)

Rule	Value	Why
Ground	Solid L2 island	Clean reference
Clearance	20mm from motors	Noise
ADC Traces	<50mm	Accuracy
Shunt to LM393	Short	Spike fidelity

6.13 Validation Procedure

Test	Expected
3-Pin Motor	ADC sees pulse
2-Pin Motor	LM393 toggles
Dual Motor	Both channels independent

Test	Expected
Noise Test	No false triggers

---

7. I/O Expansion + Curtain Sensors + PCB-B Auto ID Domain (Modularity & Machine Abstraction Layer)

This block turns your controller into a **universal vending platform**. It lets the same PCB-A work across Seaga, TCN, XY, and future machines — just by changing PCB-B.

7.1 Functional Overview

```
ESP32 (I2C)
   |
MCP23017 (16 GPIO)
   |
+---------------------+----------------------+
|                     |                      |
Curtain Sensors   Fan / Relay Control   PCB-B ID Network
(3/4 pin)          (Machine Cooling)   (Resistor Ladder)
```

7.2 MCP23017 I/O Expander (Core Device)

Device

Part	Spec
MCP23017	16-bit I2C GPIO

Power & Decoupling

```
3.3V_DIGITAL
   |
 FB701
   |
 VDD
   |
 C701 100nF
   |
 GND_DIGITAL
```

Address Selection

Pin	Connection	Result
A0	GND	Addr bit 0
A1	GND	Addr bit 1
A2	GND	Addr bit 2

Base Address = `0x20`

7.3 I2C Interface

Shared bus from ESP32:

Net	MCP23017 Pin
SDA	SDA
SCL	SCL

Pull-ups already from Section 4

Add:

Ref	Value	Why
R701/R702	33Ω	EMI damping

7.4 Curtain Sensor Types

Sensor	Pins	Voltage	Notes
Seaga	3	5V	Digital output
TCN	3	24V	Needs isolation
XY	4	24V + 5V	Mixed rail

7.5 5V Curtain Sensor Interface

Circuit (Per Channel)

```
SENSOR_OUT ── R801 (1k) ── MCP23017 GPIO
                         |
                        C801
```

```
                   |
                  GND
```

Part	Value	Why
R801	1k	Input protection
C801	100nF	Noise filter

7.6 24V Curtain Sensor Interface (Isolated)

Optocoupler Method

```
24V_SENSOR ── R802 (4.7k) ──|> LED  PC817
                             |
                            GND

PC817 OUT ── R803 (10k pull-up) ── 3.3V
              |
             MCP23017 GPIO
```

Part	Value	Why
R802	4.7k	LED current limit
R803	10k	Logic pull-up

7.7 Fan & Relay Control

Relay Driver

```
GPIO → R901 (1k) → ULN2803 IN
ULN2803 OUT → Relay Coil → 24V
Diode internal in ULN
```

Fan Control (MOSFET)

```
GPIO → R902 (100Ω) → MOSFET Gate
Fan → 24V
Flyback Diode → Fan
```

7.8 PCB-B Auto Identification Network

Principle

PCB-B carries a **resistor to GND** that encodes machine type. PCB-A reads voltage via ADC or MCP23017.

Circuit

```
3.3V
 |
 RREF (10k)
 |
ID_NET ──────→ ESP32 ADC / MCP GPIO
 |
R_ID (PCB-B)
 |
GND
```

ID Table

Machine	R_ID
Seaga	1k
TCN	2.2k
XY	4.7k
Future	10k

7.9 Test Points

Ref	Net
TP70	SDA
TP71	SCL
TP72	SENSOR_5V_1
TP73	SENSOR_24V_1
TP74	FAN_CTRL
TP75	ID_NET

7.10 PCB Layout Rules (Sensor Zone)

Rule	Value	Why
Isolation	≥10mm from motors	Noise
Opto Gap	Slot under opto	Safety
Trace Width	0.25mm	Logic
Ground	Digital island	Clean IO

7.11 Validation Checklist

Test	Expected
I2C Scan	MCP23017 present
5V Sensor	GPIO toggles
24V Sensor	Opto LED toggles
Fan	Spins on command
ID Detect	Correct machine

Next Section:

> **PCB-B Card Edge Design + Connector Mapping + Mechanical Rules**

This is where your system becomes **physically reliable in the field**.

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8. PCB-B Card Edge + Connector Mapping + Mechanical & Manufacturing Rules

This section defines the **physical reliability layer** of your system. A bad card-edge design will cause intermittent motor failures, false feedback, and field returns — even if electronics are perfect.

You are using a **64-pin (2×32) card edge system** matching X2549WR-2x32A-PTV10 / TE 5650118-1.

8.1 Dimensions (From Your Attached Image)

Critical Measurements

Parameter	Value	Why It Matters
Contact span (active pads)	**83.82 mm**	Must match connector spring pitch exactly

Parameter	Value	Why It Matters
Overall edge width	**83.907 mm**	Mechanical fit tolerance
PCB-B width	**130.00 mm**	Matches PCB-A width
Pad count	64 (32 per side)	Full matrix + sensors + power
Pad orientation	Vertical, edge-facing	Proper wipe action

Tolerances (Manufacturing)

Feature	Tolerance
Edge width	±0.10 mm
Pad pitch	±0.05 mm
Chamfer angle	20–30°

8.2 Card Edge Pad Geometry (Industrial Spec)

Feature	Value	Rule
Pad width	1.20 mm	Spring contact area
Pad height	6.00 mm	Insertion depth
Pad pitch	2.54 mm	Matches connector
Copper thickness	2oz	Wear resistance
Surface finish	**ENIG / Hard Gold**	1000+ insert cycles

Keepout

Zone	Rule
3 mm from edge	No vias, no traces
5 mm from pads	No tall components

8.3 Pin Numbering Convention

Viewing Rule

When looking at PCB-B **from component side, edge facing down**:

- Left side = Pins 1–32 (Side A)
- Right side = Pins 33–64 (Side B)

8.4 64-Pin Industrial Mapping Table

Side A (Pins 1–32)

Pin	Net	Description
1	GND	Ground
2	GND	Ground
3	+24V	Motor Power
4	+24V	Motor Power
5	ROW_1	Motor Row Enable
6	SLOT_1	Motor Slot
7	ROW_2	Motor Row Enable
8	SLOT_2	Motor Slot
9	ROW_3	Motor Row Enable
10	SLOT_3	Motor Slot
11	ROW_4	Motor Row Enable
12	SLOT_4	Motor Slot
13	ROW_5	Motor Row Enable
14	SLOT_5	Motor Slot
15	ROW_6	Motor Row Enable
16	SLOT_6	Motor Slot
17	FB_1	Feedback / Sensor
18	FB_2	Feedback / Sensor
19	FB_3	Feedback / Sensor
20	FB_4	Feedback / Sensor
21	SENSOR_5V_1	Curtain Sensor
22	SENSOR_5V_2	Curtain Sensor
23	SENSOR_24V_1	Curtain Sensor
24	SENSOR_24V_2	Curtain Sensor
25	FAN_CTRL	Cooling Fan
26	RELAY_CTRL	Refrigeration Relay
27	ID_NET	PCB-B ID
28	SDA	I2C

Pin	Net	Description
29	SCL	I2C
30	+5V	Logic Power
31	+3.3V	Logic Power
32	GND	Ground

Side B (Pins 33–64)

Pin	Net	Description
33	GND	Ground
34	+24V	Motor Power
35	ROW_7	Motor Row Enable
36	SLOT_7	Motor Slot
37	ROW_8	Motor Row Enable
38	SLOT_8	Motor Slot
39	ROW_9	Motor Row Enable
40	SLOT_9	Motor Slot
41	ROW_10	Motor Row Enable
42	SLOT_10	Motor Slot
43	ROW_11	Motor Row Enable
44	SLOT_11	Motor Slot
45	ROW_12	Motor Row Enable
46	SLOT_12	Motor Slot
47	FB_5	Feedback
48	FB_6	Feedback
49	FB_7	Feedback
50	FB_8	Feedback
51	FB_9	Feedback
52	FB_10	Feedback
53	FB_11	Feedback
54	FB_12	Feedback
55	NC	Reserved
56	NC	Reserved

Pin	Net	Description
57	TEMP_DATA	Temp Sensor
58	BUZZER	Buzzer Control
59	UART_TX	Service Port
60	UART_RX	Service Port
61	OE	Motor Enable
62	GND	Ground
63	+5V	Logic Power
64	GND	Ground

8.5 PCB-B ID Resistor Placement

Rule	Why
Place within 20mm of edge	Reduces noise pickup
Guard with GND trace	ADC stability
1% tolerance resistor	ID accuracy

8.6 Mechanical Reinforcement

Feature	Spec	Why
Mount Holes	M3 plated	Strain relief
Edge Stiffener	Optional FR4 bar	Prevent flex
Connector Support	Nylon post	Vibration

8.7 Manufacturing Rules

Parameter	Value	Why
Surface Finish	ENIG / Hard Gold	Wear
Bevel	30°	Smooth insertion
Solder Mask	Open on pads	Contact
Electrical Test	100%	Reliability
AOI	Required	Defect detection

8.8 Field Service Design Rules

Rule	Why
Label pin-1 on silkscreen	Tech clarity
Color band on edge	Orientation
QR code	Board revision

8.9 Validation Checklist

Test	Pass Condition
Fit Test	Slides smoothly
Wiggle Test	No contact loss
Power Load	<50mV drop
100 Insert Cycles	No wear

8.10 EasyEDA Drawing Steps

1. Draw PCB-B outline: **130mm × custom height**
2. Draw card edge line
3. Place 64 rectangular pads
4. Set pad pitch = 2.54mm
5. Set mask opening = 0
6. Add chamfer on board edge
7. Assign nets from mapping table

This Completes Your Industrial VMC Hardware Platform

At this point, you have: - Modular master/slave architecture - Industrial motor power handling - Clean analog feedback - Universal sensor support - Machine auto-detection - Field-serviceable mechanical design

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If You Want, Next I Can Generate

- **Full EasyEDA Footprint for 64-pin Card Edge (JSON / LCSC ready)**
- **Netlist CSV for PCB-A & PCB-B**
- **JLCPCB Manufacturing Rule File**
- **Silkscreen Label Pack**
- **Bring-Up & Factory Test Procedure (Step-by-Step)**

This is now a **real OEM-grade VMC controller design**, not a hobby board.