Node Card Assembly Guide

Introduction

See the How to Use Assembly Guides for detailed instructions.

In conjunction with the Node Bus Hub, the **LCC Fusion Node Card** provides an LCC compatible Node with ON/OFF control for up to 8 separate I/O devices. Typically, in an LCC Fusion Project LCC Fusion Node Cluster arrangement, there will be a Node Bus Hub, with one LCC Fusion Node Card, an optional I/O cards.

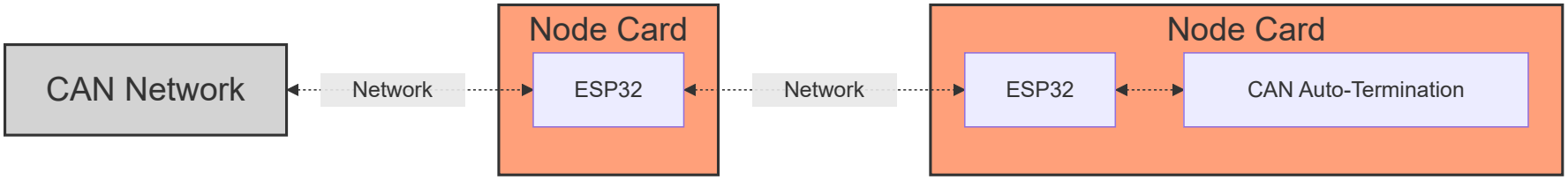
The **LCC Fusion Node Card** can be implemented with a number of **optional** features:

1. Power Supply options (see Power Module for more details):
    1. 12V+ input via a network cable (CAT5/6), USB-C socket, 5557 ATX connection, or a DC-005 barrel connection.
    2. 12V+ output via 5557 ATX connection for powering other LCC Fusion Node Cards.
    3. 5V+ output via USB-C for powering low voltage devices (e.g. RPI).
    4. 12V+ or input power selection for the LCC Fusion Node Bus Hub to control the high voltage for the I/O cards.
2. CAN serial connection via a network cable (CAT5/6) or connectors (JST XH or Spring terminal).
3. CANable adapter for Windows USB to CAN connection for JMRI integration.
4. CDI reset button (hold for 10 seconds to reset the CDI to factory setting)
5. Reset button to restart the Node.
6. LCC Fusion Node Bus Hub(RJ45) network cable connection to connect with a remote LCC Fusion Project **Node Bus Hub**

CAN Communications

The **LCC Fusion Node Card** connects to a CAN Network, enabling communication of **LCC Events**. It features two **RJ45 sockets** for easy **in/out** connections, allowing multiple Node Cards to be daisy-chained together. To simplify the network setup, the Node Card includes an **auto-termination circuit**, ensuring the correct 120 Ω termination is automatically applied to the last device in the chain, eliminating manual setup.

Below is a diagram illustrating the daisy-chaining of Node Cards via their RJ45 sockets with automatic CAN termination:

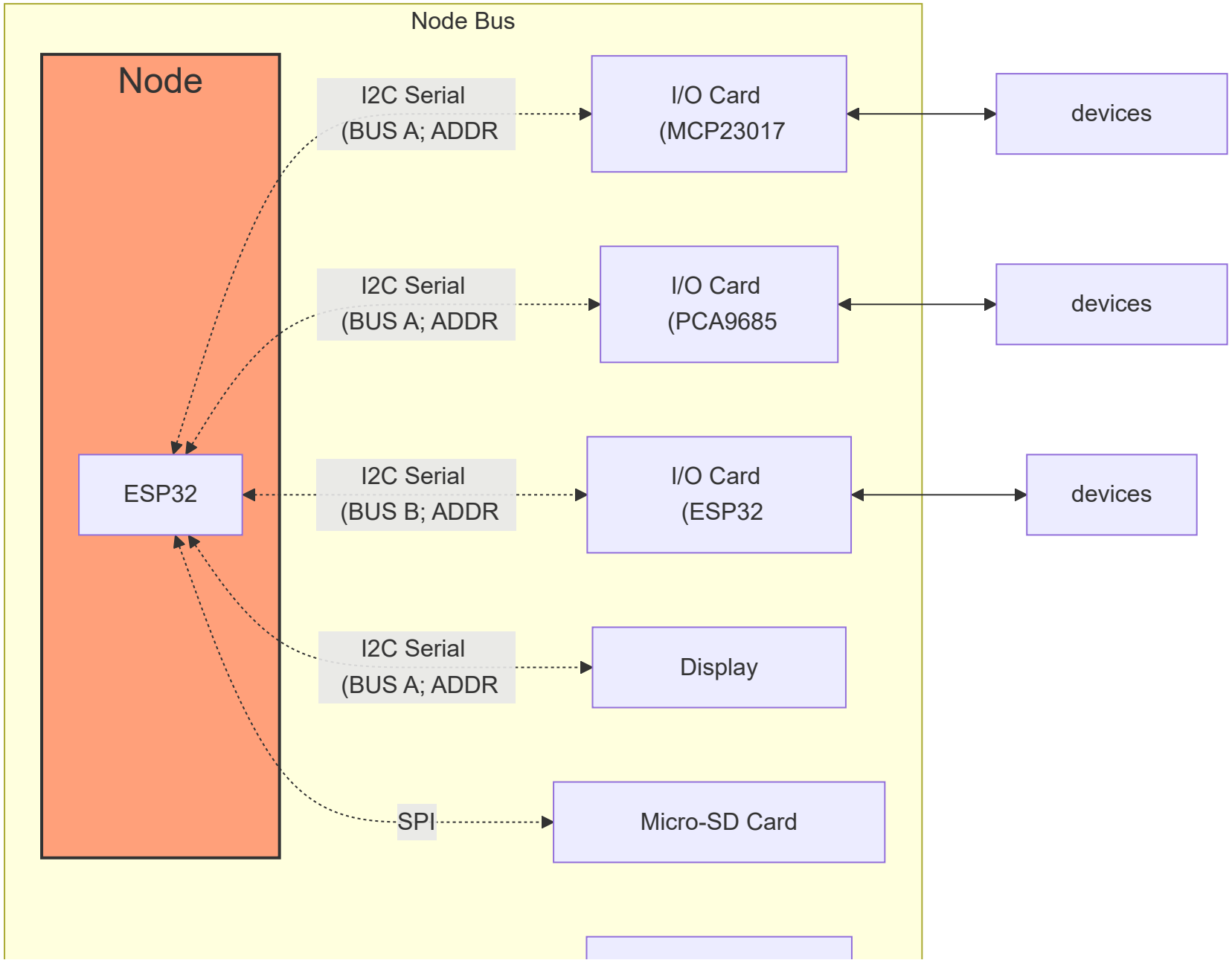


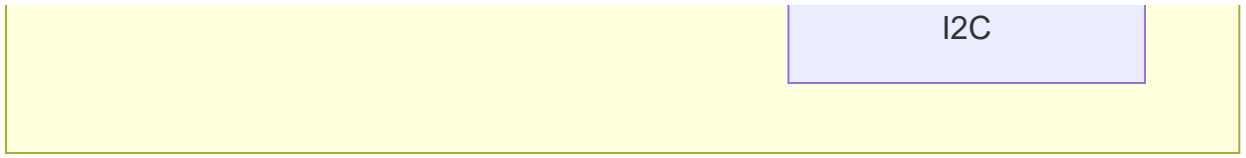
I2C Communication

The **LCC Fusion Node Card** supports **I2C serial communication** to interface with various I/O cards. Each device on the I2C bus is assigned a communication address and an address offset. The Node Card supports two I2C buses (Bus A and Bus B) with offsets ranging from 0 to 7.

Pullup resistors are used to "condition" the I2C lines (SDA and SCL), ensuring proper signal levels by pulling the lines to a high state when not actively driven. Conditioning of the I2C to maintain proper voltage levels is handled automatically.

Below is a diagram showing how I2C serial communication is used between the **Node Card** and multiple I/O cards:


Node Bus
Node
ESP32
I2C Serial
(BUS A; ADDR
I/O Card
(MCP23017
devices
I2C Serial
(BUS A; ADDR
I/O Card
(PCA9685
devices
I2C Serial
(BUS B; ADDR
I/O Card
(ESP32
devices
I2C Serial
(BUS A; ADDR
Display
SPI
Micro-SD Card

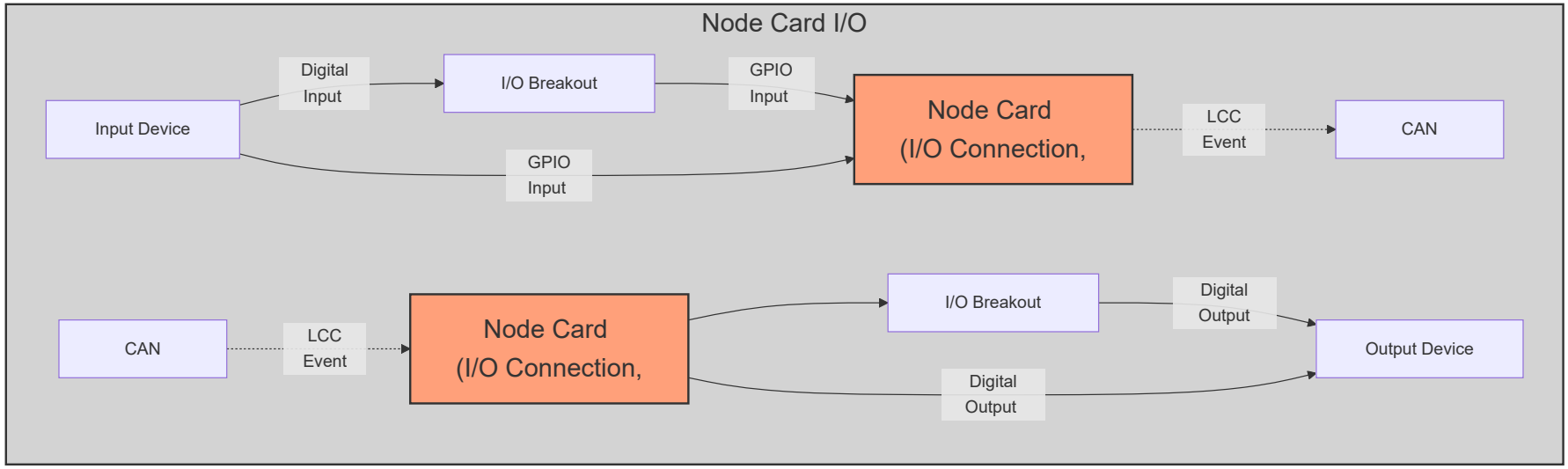


I/O Connections

The **LCC Fusion Node Card** features an **RJ45 socket** for connecting up to **8 I/O devices**, enabling direct interaction with a variety of peripherals. Supported I/O devices include:

- Touch pads
- LEDs
- Relays
- DC motors
- Buzzers
- Solenoids / Electromagnets
- Fans

Below is a diagram showing how a network cable is used to connect multiple I/O devices directly to the Node Card via its RJ45 socket:



Specifications

Specifications for the Power-CAN Card include:

> When using multiple Node Cards or Quad-Node Cards, consider using ATX, terminal, or DC-005 barrel connector to provide 5V @ 3A to the Node Bus Hub.

Characteristic	Value
I/O: Max Input / Output Lines	8
Nodes: Max number of Nodes (assuming 100mA avg per Node ESP32)	30
Node Cards: Max number of Node Cards per Node Cluster	2^1
Input: Max supply voltage (limit of TVS Diode, SMBJ18V)	18V
Input: Max supply current via CAN Bus network cable (limited by network cable's 2 combined power wires)	1.2A

Characteristic	Value
Input: Max supply current via ATX 5557, Spring/Screw Terminal Connector, or DC-005 connector	3A
Input: Max supply current USB-C connector (without 12V regulator, connector limit)	2A
Output: Max 3V3 output current (LM1117-3V3 regulator limitation)	800mA
Output: Max supply current to output ATX 5557 or Spring/Screw Terminal connectors	3A
Output: Max 5V output current to Node Bus Hub	3A[2,3]
Output: Max 12V to the Node Bus Hub (L7812 regulator limitation)	1.5A[4,5]
Output: Max output current via USB-C	2A
Output: Max output voltage to ATX 5557 or Spring/Screw Terminal Connector	Input Voltage minus ~0.4 - 1.7V[6]

1. Limit of Node Bus Hub (3A) within the Node Cluster (one or more Node Bus Hubs connected together via pin headers)
2. The LM2596-ADJ switching regulator has a maximum current rating of 5A, but the output is limited to 3A due to:
    - PCB traces (54 mil width), Vias (0.6mm holes), Diodes (SS310), and
    - 3A polyfuse (resettable).
3. The 5V switching regulator (LM2596-ADJ) operates with approximately a 10% efficiency loss, meaning the input current may exceed the output current by this margin.
4. Limit of 1.5A by 12V voltage regulator (L7812CV).
5. The 12V linear regulator (L7812) dissipates power as heat, resulting in an efficiency of around 85% (or ~15% efficiency loss), meaning the input current may exceed the output current by this margin.
6. Voltage drop is caused by reverse voltage protection (two SS310 diodes in series)

Below is an updated version of your Node Card documentation with an additional **Indicators & Additional Features** section covering the requested items.

How It Works

The **Node Card** supports both **power distribution** and **CAN network connectivity** across LCC Fusion devices. It connects to the **Node Bus Hub** and enables stable power and reliable communication between multiple Node Cards and I/O modules. Key protections against network fluctuations and reverse voltage are built in; see Protection for more.

CAN Network

The Node Card includes connections to the CAN Network for communications with other LCC protocol–enabled devices. Both network cable or 2/3-wire connections are supported.

> The 2/3-wire connection could be use to connect with other LCC CAN enabled devices or to a (isolated) CANable Module connected to a computer for use with JMRI.

Correct termination of the CAN network is essential for reliable data transmission. To meet this, the **Node Card** and **Quad-Node Card** support auto-termination by detecting low voltage on the CAN network and applying a 120 Ω pullup resistor as needed.

Power Supplied to Local and Remote Node Bus Hubs

The Node Card provides regulated power to both local and remove Node Bus Hubs, with various connection and regulation options (see Protection and Connections for more details):

> **Remote Node Bus Hub:** In addition to using the Node Card's Node Bus (edge) connection to a Node Bus Hub, you can also link the Node Card to a separate (remote) Node Bus Hub for extended network coverage using a network cable.

1. The **OUTPUT POWER** selector allows users to set the power output to **12V** via a linear regulator or to bypass it, using the input supply voltage for >12V needs.
2. When set to **12V**, the **L7812CV regulator** converts the supply voltage to 12V for use by both the Node Card and the Node Bus Hub.
3. A **LM2596-ADJ** switching regulator provides a steady **5V** supply for the Node Bus Hub.
4. A **LM1117-3V3** linear regulator supplies **3.3V** to the Hub, meeting the lower voltage requirements of certain modules.
5. **Overcurrent protection** is provided by two resettable polyfuses rated at **1.5A and 3A**.
6. **Reverse polarity protection** is included via a diode across all input lines.

7. **Reverse current protection** is included via diodes on each output line.
8. **Noise filtering** is implemented with capacitors on both input and output lines to stabilize and clean the power signal.

Multiple Power Inputs/Outputs are supported via voltage regulators:

- **5V USB-C** (input or output)
- **12V output**
- **Power input** via CAN bus network cable, ATX connection, or USB-C cable. Input power overload is protected using both slow and fast-blow fuses. A fuse holder allows the replacement of fast-blow fuse, which can also be bypassed using a Jump Cap.
- **Battery Backup:** An optional **Battery Card** can provide uninterrupted power, letting the Node Card continue operation if the main supply is lost.

This modular design also supports adding multiple Node Cards to a single Node Bus Hub to expand both power capacity and CAN connectivity, enabling flexible scaling for complex automation configurations.

Indicators & Additional Features

- **Power Indicators:** Onboard LEDs for **3.3V**, **5V**, and **12V** rails let you quickly verify that each voltage is active and within spec. A **blown fuse indicator** circuit also provides a visual alert if a the fast-blow fuse trips.
- **Alert Buzzer & LED:** Firmware can drive a buzzer and an additional LED to signal warnings or errors. The number of buzzes or LED blinks can be used as a diagnostic code for troubleshooting.
- **CDI Reset & Node Reboot:** The Node Card firmware supports the use of the Node Card's tactile buttons for triggering a CDI parameter reset or rebooting connected devices, ensuring you can remotely recover or reconfigure nodes if needed.
- **I/O Devices:** the ESP32 supports connecting analog, digital, touch, and PWM devices such ase sensors, actuators, or other I/O modules for local or distributed automation tasks.

Connections

Component Designator	Connector Label	Connector Type	Connection Number	Function	Description
	NODE BUS	Card Edge	1-12	Power, Communications	Connection to Node Bus Hub
J1	**PWR IN**	USB-C[1]	V+, GND	Power In	Connection from Power Supply (14-18V, 0.5-3A)
J2	**PWR IN**	ATX 5557 RA[2]	V+, GND	Power In	Connection from Power Supply (14-18V, 0.5-3A)
J3	**PWR IN**	DC-005[1]	V+, GND	Power In	Connection from Power Supply (14-18V, 0.5-3A)
J4	**PWR OUT**	ATX 5557 RA	V+, GND	Power In	Connection to next Power-CAN Card, or Node Card (14-18V, 0.5-3A)
J5, J6	**CAN BUS**	RJ45 Socket	1-8; CAN-H, CAN-L, GND, undef, undef, GND, GND, V+	Power & CAN In/Out	Connection to/from other LCC Nodes. Pin 1 pad is square (left side, front row).
J7	**I/O**	RJ45 Socket	1-8	I/O (Digital, ADC, Touch, PWM)	Connection to input / output devices, or LCC Fusion breakout boards

Component Designator	Connector Label	Connector Type	Connection Number	Function	Description
J8	**NODE BUS**	RJ45 Socket[3]	1-8; 3V3, 5V, 12V, GND, SDA0, SCL0, SCL1, SDA1	LCC Fusion Node Bus connection	Connection to **LCC Fusion Node Bus Hub**
J9	**5V OUT**	USB-C	5V, GND	Power Out	Connection to 5V devices (e.g. RPI)
J10	**SPI / MICRO-SD MODULE**	6-Pin Header	SPI (3V3, CS, MOSI, CLK, MISO, GND)	SD Card Reader	Used for local storage
J11	**CAN I/O[4, 5]**	3-Pin Header	CAN (CAN-H, CAN-L)	CANable Device/Adapter, CAN Network	Used to connect to the CAN Network
J12	**BATT IN**	2P JST XH, screw/spring terminal	12V, GND	Battery Card	Connection to **LCC Fusion Battery Card** for power backup
J13	**I2C Display**	4-Pin Header	GND, 3V3, SCL, SDA	Display Monitor	Connection to display messages on monitor

1. Recommend a laptop power supply with a USB-C and DC-005 connectors with typically provide 18-20V and >3A (>65W) for less than $20 on Amazon.
2. Recommend using train layout accessory bus which is typically >12V.
3. Typically used to connected to a remote Node Bus Hub (board) as an alternative to using the **NODE BUS** edge connection to directly connect to a local **Node Bus Hub**. Pin 1 pad is square (left side, front row).
4. Provides an alternative method of connect to the **CAN Network**. A **CANable** adapters attach to computers via USB.
5. This connection does **NOT** provide a **galvanic isolation** link to the **CAN Network** for a electrical isolation between the **CAN Network** and **LCC Fusion** devices. For protection, insure that the **CANable Adapter** provides the required isolation.

Protection

The LCC Fusion Node Car d is equipped with several protection components to ensure reliable operation and safeguard against electrical faults. Below is an overview of each protection element integrated into the LCC Fusion Node Card and its role:

Here's the updated row for low voltage detection, noting the minute-based alerts triggered until a reboot:

Protected Component	Protection Component	Function	Specifications	Location
Entire Board (Relays, Devices, Voltage Regulator)	**Crowbar Diode, Resettable Fuse**	Crowbar Protection protects against reverse polarity by short-circuiting the power supply when connected backward, blowing the fuse to protect the circuit	Diode becomes forward-biased if reverse polarity occurs	Across the power supply input (ACC V+ to ACC GND) C V+ to ACC GND)
Entire Board (ESP32, Devices)	**Low Voltage Detection Circuit**	Monitors 3.3V rail for voltage drops below 3.0V, triggering an alert message and buzzer every minute until reboot to prevent brownout conditions that may cause instability	Voltage threshold set to 3.0V	ADC pin connected to the 3.3V output from onboard regulator
Entire Power-CAN Card	**Fast Blow Fuse**	Protects from current overflow	**Hold Current:** 3A	In series with the incoming Vcc line

Protected Component	Protection Component	Function	Specifications	Location
Entire Power-CAN Card	**Polyfuses**	Protects from sustained overcurrent conditions by increasing resistance when the 3V3 or 5V current exceeds 1.5A. Resets once the fault condition is cleared.	**Hold Current:** 1.5A	In series with the 5V, 3V3 output lines
Entire Power-CAN Card	**TVS Diode SMBJ18A**	Protects from high-voltage transients by clamping voltage spikes, pthem from reaching sensitive components.	**Stand-off Voltage:** 18V **Clamping Voltage:** 29.2V	Across the incoming Vcc and GND lines
CAN Bus	**Automatic Termination**	Provides proper termination to prevent signal reflections on the CAN bus.	**Value:** 2x 60 Ωs in series (120 Ωs)	Across CANH and CANL lines, automatically applied based on CAN network voltage while using a low-pass filter to measure peak voltage.
CAN Bus	**ESD Protection Diode PESD1CAN**	Protects the CAN bus lines from electrostatic discharge and voltage spikes.	**Reverse Stand-off Voltage (Vr):** 24V **Clamping Voltage (Vc):** 40V	Across CANH to GND and CANL to GND
I2C Bus (each set)	**ESD Protection Diode PESD1CAN**	Protects the CAN bus lines from electrostatic discharge and voltage spikes.	**Reverse Stand-off Voltage (Vr):** 24V **Clamping Voltage (Vc):** 40V	Across CANH to GND and CANL to GND

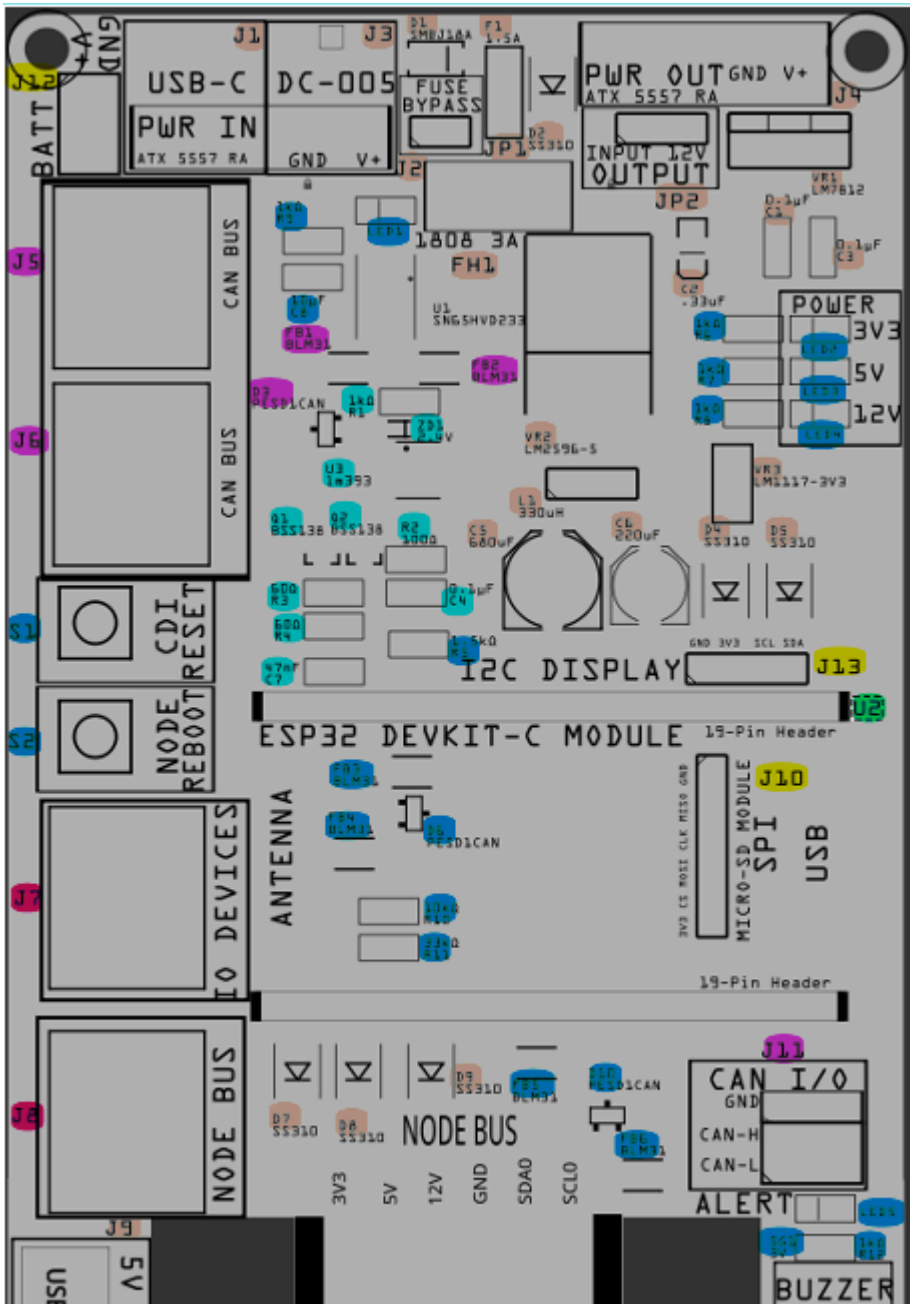
Protected Component	Protection Component	Function	Specifications	Location
CAN Bus	**BLM31PG121SN1L Ferrite Beads**	CAN Network Bus Data Line Noise Suppression Ferrite Bead		In series with the CAN network lines
I2C Bus (each set)	**BLM31PG121SN1L Ferrite Beads**	CAN Network Bus Data Line Noise Suppression Ferrite Bead		In series with the I2C network lines
ESP32 Vcc	**Decoupling Capacitor**	Filters out high-frequency noise and transient voltage spikes from the power supply, ensuring stable voltage for the ESP32.	**Value:** 0.1 µF, 10uF ceramic	Integrated into DevKit-C Board
LM2596-ADJ Regulator	**Output Capacitor**	Filters out high-frequency noise and transient voltage spikes from the output, ensuring stable 5V regulation.	**Value:** 680 µF electrolytic	Across the output (5V) and GND
L7812CV Regulator	**Output Capacitor**	Filters out high-frequency noise and transient voltage spikes from the output, ensuring stable 12V regulation.	**Value:** 10 µF ceramic	Across the output (12V) and GND
Ground Bus	**48mil Ground Bus**	Provides a low-resistance path for all protection components, ensuring effective grounding and noise suppression.	**Width:** 48 mil	Used by all protection components

Summary

These protection components work together to safeguard the LCC Fusion Node Card from various electrical faults. The CAN termination resistor ensures proper signal integrity on the CAN bus, while the ESD protection diodes protect the CAN bus and I2C lines from voltage spikes and electrostatic discharge. The decoupling capacitor filters out noise and transient voltage spikes, ensuring stable power for the ESP32. The ferrite bead suppresses high-frequency noise on the I2C lines. The input Vcc is protected by the Power Module, which includes a polyfuse and TVS diode for overcurrent and overvoltage protection. Together, these components ensure the LCC Fusion Node Card operates reliably in a potentially harsh electrical environment.

Assembly-Configuration Options

The **Node Card** supports multiple assembly configurations to fit various use cases.


BATT +
GND
J12
USB-C
PWR IN
ATX 5557 RA
J1
DC-005
GND V+
J3
FUSE BYPASS
JP1
PWR OUT
ATX 5557 RA
GND V+
J4
INPUT 12V
OUTPUT
JP2
J2
1808 3A
FH1
POWER
3V3
5V
12V
CAN BUS
J5
J6
CDI RESET
S1
NODE REBOOT
S2
I2C DISPLAY
GND 3V3 SCL SDA
J13
ESP32 DEVKIT-C MODULE
19-Pin Header
U2
ANTENNA
J10
MICRO-SD MODULE
SPI
USB
IO DEVICES
J7
19-Pin Header
NODE BUS
J8
J11
CAN I/O
GND
CAN-H
CAN-L
ALERT
BUZZER
3V3
5V
12V
GND
SDA0
SCL0
J9

The **PCB diagram** shown above highlights different components based on their associated configuration. Each **color-coded component** corresponds to a specific configuration, which is further detailed in the table below.

To use this reference effectively:

- **Match the Colors:** Each assembly option in the table has a **matching color** in the PCB diagram. This helps identify which components are needed for a specific configuration.
- **Locate Components Quickly:** The highlighted **component designators** (e.g., **D5, J1, JP2**) on the PCB indicate where each part is placed.
- **Identify Required vs. Optional Parts:** The table differentiates between **required components** (essential for functionality) and **optional components** (enhancements or variations).
- **Cross-Reference for Clarity:** If you're unsure about a part's placement, use the **designator labels** on the PCB along with the descriptions in the table.

This approach ensures a **clear, visual guide** for assembling the Node Card based on your specific needs.

Configuration	Required/Optional	Description	Required Components	Optional Components
ESP32 & I2C Support	**Required**	Provide ESP32 DevKit-C Module Support for Node	• **ESP32 DevKit-C Headers** (U1) • I2C Noise Filtering: Ferrite Beads **FB3, FB4, FB5, FB6**	I2C Bus Protection: Diode **D6, D10** (for ESD protection on the I2C data bus) • **Reboot Button** (S1) • **CDI Reset Button** (S2)
CAN Termination Support	**Required**	**I2C Low Voltage Dection and Correction**	• **Voltage Comparator** (U3, ZD1, R1, R2) • **120Ω Switching Circuit** R3, R4, C7, Q1, Q2)	None

Configuration	Required/Optional	Description	Required Components	Optional Components
Power-Input	**Required**	Provides power input connectors with high-voltage transient protection and input filtering.	• **TVS Protection:** diode **D1** • **Reverse-polarity Protection:** diode **D2** •**Reverse Current Protection** diodes **D4, D5, D8** • **Overcurrent Protection**: Slow-burn fuse **F1** • **3A Fuse Holder**: **FH1** with 3A fuse ***AND/OR*** bypass selectable via header **JP2**	• USB-C Power In Socket (**J1**) • Wired Power In Connector **J2** • DC-005 Power In Connector (**J3**)
3.3V Output	**Required**	Supplies regulated 3.3V to the Node Bus.	• **3.3V Regulated Output** (VR3) • **Reverse Current Protection**: Diode **D7**	None
5V Output	**Required**	Supplies regulated 5V to the Node Bus with proper filtering and protection.	• 5V Regulated Output: Buck regulator **VR2** accompanied by input filter capacitors **C1** (680 µF). **C2** (220 µF), **C3** (0.1 µF), **C4** (0.33 µF), and **C9** (1nF), inductor **L1**, voltage divider resistors **R13** (3.3KΩ) and **R14** (1KΩ) • Reverse/Output Protection: Diode **D8**	• 5V USB-C Output Connector (**J9**)

Configuration	Required/Optional	Description	Required Components	Optional Components
12V Output	**Optional**	Provides regulated 12V (or higher) for powering external devices and the LCC Fusion Node Bus Hub.	• 12V Regulated Output: Voltage regulator **VR1** • Reverse/Output Protection: Schottky diodes **D4**, **D5**, **D9** • Power Selection 3-Pin Header **JP2** with Jumper cap **SH1** (set to INPUT when NOT using the 12V regulator)	• 12V Output Connectors: **J4** (for 12V @ 3A output)
CAT-Wired CAN BUS Option	**Optional**	Enables wired CAN Bus connectivity over CAT network cable, supporting data exchange with other LCC Fusion Nodes.	• Reverse Polarity Protection: Diode **D10** (protects input power from CAN Bus connectors) • CAN Bus Noise Suppression: Ferrite beads **FB1** and **FB2**	• CAN Bus Connections: RJ45 connectors **J5** and/or **J6** • ESD Protection: Diode **D3**
Indicators and Controls Support Option	**Optional**	Setup for **Power Indicators** and **Firmware Controls**	• **Power Indicators** (LED2, LED3, LED4, R6, R7, R8) • **Voltage Divider for 12V Detection** (R10, R11)	• **Blown Fuse Indicator** (LED1, R9, C8) • **Buzzer** (SG1) • **ALERT Indicator** (LED5,R12)
Battery Backup Support Option	**Optional**	Enables battery backup for increased system availability.	• Battery Connector: **J12**	None
Increased File Storage Option	**Optional**	Setup for connecting **Micro SD-Card Reader** (use is TBD)	• **SPI Connector** (J10)	None

Configuration	Required/Optional	Description	Required Components	Optional Components
Display Mointor Option	**Optional**	Setup for connecting an I2C enabled display monitor	• **I2C Connector** (J13)	None
Remote Node Bus Hub Support Option	**Optional**	Setup for connecting to a remote **Node Bus Hub**	• **Network Cable Connection** to remote Node Bus Hub (J8)	None
I/O Device Support Option	**Optional**	Setup for supporting **I/O Devices** (e.g., LEDs, buttons) through network cable.	• **I/O Device Connector** (J7)	None

Components List

PCB for the LCC Fusion Node Card can be ordered from any PCB fabricator using these Gerber Files.

PCB Components - listing of components used for PCB assembly

PCB Parts - listing of parts used for PCB assembly

Below is a list of the PCB components used for this card (see diagram on below for reference):

Here's the updated table with the count, type, and package columns added:

Component Identifier	Count	Type	Value	Package	Required?	Purpose
Capacitors						
C1, C3	2	Ceramic Capacitor	0.1uF	1206 SMD	Required	IC protection

Component Identifier	Count	Type	Value	Package	Required?	Purpose
C2	1	Tantalum Capacitor	0.33uF	3216 SMD	Required	IC protection
C4	1	Ceramic Capacitor	0.1uF	1206 SMD	Required	Filters high-frequency noise from CAN signals, smoothing voltage for the comparator
C5	1	Polymer Capacitor	680uF, 10V	8x12mm, PTH	Required	Used by 5V voltage regulator for input filtering
C6	1	Polymer Capacitor	220µF, 10V	6.3x5.8mm , SMD	Required	Used by 5V voltage regulator for input filtering
C7	1	Ceramic Capacitor	47uF	1206 SMD	Required	CAN termination circuit
C8	1	Ceramic Capacitor	10uF	1206 SMD	Required	Used by blow fuse circuit to cause slow LED fade in/out
C9	1	Capacitor-Ceramic	1nF	1206 SMD	Required	Smooths the LM2596S-ADJ output voltage.
Diodes						

Component Identifier	Count	Type	Value	Package	Required?	Purpose
D1	1	TVS Diode	SMBJ18A	SMB SMD	Optional	Protects from high-voltage transients (>29V)
D2, D4, D5, D7, D8, D9	6	Schottky Diode	SS310	SMA	Required	Reverse polarity and current protection
D3, D6, D10	3	ESD Diode	PESD1CAN	SOT-23 SMD	Optional	I2C data bus ESD protection
ZD1	1	Zener Diode	2.4V	BZT52	Required	2.4V reference voltage
Fuses & Protection						
FH1	1	Fuse Holder	1808 with 3A	SMD	Required (unless bypassed via JP1)	Protects from sustained overcurrent conditions
F1	1	PTC Polymer Fuse	JK30, 1.5A, 16V (or more)	5.1mm pitch, PTH	Required	Overcurrent protection
Filters & Noise Suppression						
FB1, FB2	2	Ferrite Bead	BLM31PG121SN1L	1206 SMD	Required	CAN Network Bus Data Line Noise Suppression Ferrite Bead

Component Identifier	Count	Type	Value	Package	Required?	Purpose
FB3, FB4	2	Ferrite Bead	BLM31PG121SN1L	1206 SMD	Required	I2C Data Line Noise Suppression Ferrite Bead
Connectors						
J1	1	USB-C Socket	4-Pin	SMD	Optional	Power input connector to power the LCC Fusion Node Card when power is **not** being supplied via the CAN Network Bus network cable
J2	1	Connector	5557 ATX RA	PTH	Optional	Power input connector to power the LCC Fusion Node Card when power is **not** being supplied via the CAN Network Bus network cable

Component Identifier	Count	Type	Value	Package	Required?	Purpose
J3	1	Power Jack	DC-005	PTH	Optional	Power input connector to power the LCC Fusion Node Card when power is **not** being supplied via the CAN Network Bus network cable
J4	1	Connector	5557 ATX RA	PTH	Optional	Power input connector to power the LCC Fusion Node Card when power is **not** being supplied via the CAN Network Bus network cable
J5-J8	4	RJ45 Socket	8P8C	PTH	Optional	CAN Bus and I/O networking
J9	1	USB-C Socket	4-Pin	SMD	Optional	Power output connector for external devices
J10	1	Header	6-Pin Male	PTH	Optional	Mounting for Micro-SD Reader Module

Component Identifier	Count	Type	Value	Package	Required?	Purpose
J11-J12	2	Female Headers	19-Pin	PTH	Required	Mounting for ESP32 DevKit-C module
J13	1	Header	4-Pin	PTH	Optional	Mounting for I2C display monitor as a serial monitor
Inductors & Resistors						
L1	1	Inductor	33uH	8x10mm, PTH	Required	Used for 5V voltage regulation
R1	1	Resistor	1k Ω	1206 SMD	Required	Current limiting for reference voltage
R2	1	Resistor	100 Ω	1206 SMD	Required	Low Pass Filter for low signal detection
R3, R4	2	Resistor	60 Ω	1206 SMD	Required	CAN termination circuit
R5	1	Resistor	1.5k Ω	1206 SMD	Optional	Part of CDI Factory Reset circuit

Component Identifier	Count	Type	Value	Package	Required?	Purpose
R6-R9, R12	5	Resistor	1k Ω	1206 SMD	Optional	Current limiting for power output and alerts LEDs
R13	1	Resistor	3.3k Ω	1206 SMD	Required	Regulator voltage divider (R2)
R14	1	Resistor	1k Ω	1206 SMD	Required	Regulator voltage divider (R1)
Switches & Indicators						
LED1-LED5	5	LEDs	Red/Green	1206 SMD	Optional	Status and alert indicators
S1, S2	2	Tact Button Switch	N/A	SMD	Optional	Factory reset or reboot buttons
SG1	1	Buzzer	3V	Piezo Active Buzzer, 9650-5V, SMD	Optional	Buzzer for firmware generated error/warning alerts
ICs						
U1	1	CAN Transceiver	SN65HVD233DR	SMD	Required	CAN Communications

Component Identifier	Count	Type	Value	Package	Required?	Purpose
U2	1	MCU (Processor)	ESP32 DevKitC-V4 Module /w ESP32-WROOM-32D 4MB	PTH, 38-Pin wide	Required	Main processor for Node Card
U3	1	Voltage Comparator	LM393 or LM2903N	SO-8, SMD	Required	Detects low voltage in I2C lines
Voltage Regulators						
VR1	1	Voltage Regulator	L7812CV	TO-220 PTH	Optional	12V regulator for Node Bus Hub
VR2	1	Voltage Regulator	LM2596S-ADJ	SMD	Required	5V regulator for ESP32 & Node Bus Hub
VR3	1	Voltage Regulator	LM1117-3V3 IC	SMD	Required	3.3V regulator for Node Bus Hub

Tools Required

> List of recommended tools.

Safety Precautions

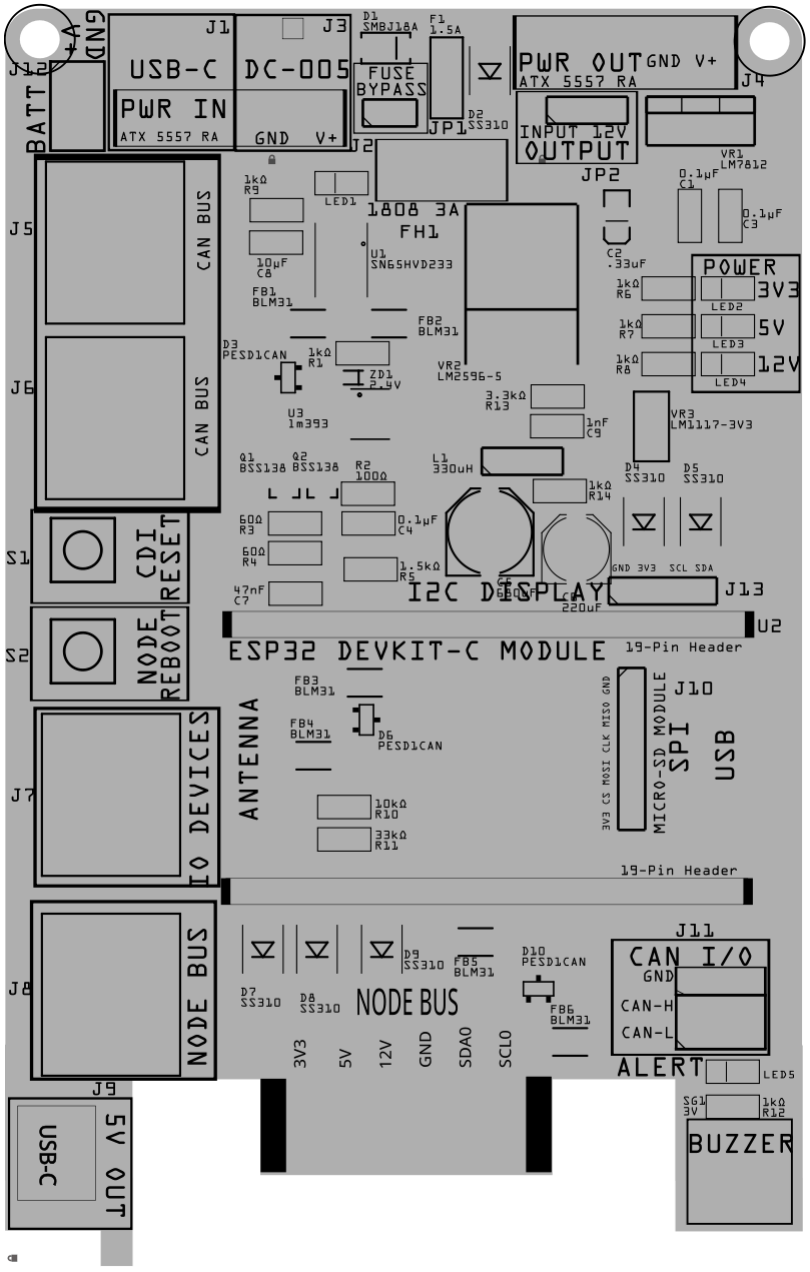
- See Safety Precautions.

Assembly Instructions

Below are the high level steps for assembly of the LCC Fusion Node Card:

1. Clean PCB with alcohol to remove residue. See Cleaning PCB for details.
2. When using a PCB stencil to apply the paste, align the stencil over the PCB using the 2 Tooling Holes located at the top and bottom of the card. There are very small holes with no labels or markings. Use a thick straight pin or wire for the alignment, pushing down into a soft foam surface to hold the pin/wire in place.

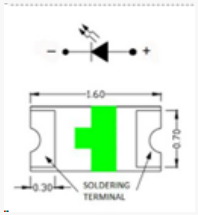
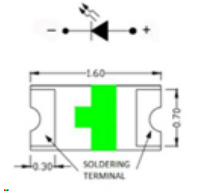
> See also: Soldering Tips


BATT +
GND
J12
USB-C
DC-005
J1
J3
PWR IN
ATX 5557 RA
GND V+
D1 SMBJ18A
F1 1.5A
FUSE BYPASS
JP1
D2 SS310
PWR OUT
ATX 5557 RA
GND V+
J4
INPUT 12V
OUTPUT
JP2
J2
VR1 LM7812
C1 0.1µF
C3 0.1µF
1808 3A
FH1
J5
J6
CAN BUS
CAN BUS
R9 1kΩ
LED1
C8 10µF
U1 SN65HVD233
C2 .33uF
FB1 BLM31
FB2 BLM31
D3 PESD1CAN
R1 1kΩ
ZD1 2.5V
VR2 LM2596-5
U3 lm393
R13 3.3kΩ
C9 1nF
VR3 LM1117-3V3
POWER
R6 1kΩ
LED2
3V3
R7 1kΩ
LED3
5V
R8 1kΩ
LED4
12V
Q1 BSS138
Q2 BSS138
R2 100Ω
L1 330uH
D4 SS310
D5 SS310
R14 1kΩ
R3 60Ω
R4 60Ω
C4 0.1µF
R5 1.5kΩ
C7 47nF
C6 220uF
S1
CDI RESET
S2
NODE REBOOT
GND 3V3 SCL SDA
I2C DISPLAY
J13
U2
ESP32 DEVKIT-C MODULE
19-Pin Header
FB3 BLM31
FB4 BLM31
D6 PESD1CAN
ANTENNA
J10
MICRO-SD MODULE
SPI
USB
3V3 CS MOSI CLK MISO GND
R10 10kΩ
R11 33kΩ
J7
IO DEVICES
19-Pin Header
J8
NODE BUS
D9 SS310
FB5 BLM31
D10 PESD1CAN
J11
CAN I/O
GND
CAN-H
CAN-L
D7 SS310
D8 SS310
NODE BUS
FB6 BLM31
3V3
5V
12V
GND
SDA0
SCL0
ALERT
LED5
SG1
3V
R12 1kΩ
BUZZER
J9
USB-C
5V OUT

tritzing

Component Identifier	Value	Required?	Orientation
C1, C3, C4	0.1uF	Required	None
C2	0.33uF Tantalum	Required	Cathode end has a brown line and positioned towards PCB **bottom** edge
C5	680uF, 25V	Required	Anode positioned toward PCB **top** edge
C6	220uF, 25V	Required	Anode positioned toward PCB **top** edge
C7	47uF	Required	None
C8	10uF	Optional	None
C9	1nF	Required	None
D1	SMBJ18A	Optional	Cathode end has a white line and positioned towards PCB **right** edge
D2, D4, D5	Diode	Optional	Cathode end has a white line and positioned towards PCB **bottom** edge
D3, D6, D10	PESD1CAN	Optional	Fits only one way
D7, D8, D9	Diode	Required	Cathode end has a white line and positioned towards PCB **bottom** edge
FH1	Fuse Holder /w 3A	Required	None

Component Identifier	Value	Required?	Orientation
F1	1.5A Fuse	Required	None
FB1 - FB6	BLM31PG121SN1L	Required	None
J1	4-Pin	Optional	None
J2, J4	5557 ATX RA	Optional	GND pin is marked on board with square pad
J3	DC-005	Optional	Fits only one way
J5, J6	8P8C	Required	Fits only one way
J7, J8	8P8C	Optional	Fits only one way
J9	4-Pin	Optional	None
J10	6-Pin male/female	Optional	None
J11	2-P Connector	Optional	None
J12	JST XH Socket	Optional	Position GND (black wire) to PCB **right** side
J13	4-Pin	Optional	None
JP1	2-Pin male header	Optional	None
JP2	3-Pin male header	Required	None
L1	33uH	Required	None

Component Identifier	Value	Required?	Orientation
LED1	RED LED	Optional	Reference back of LED, position cathode towards PCB **top** 
LED2 - LED5	GRN LED	Optional	Reference back of LED, position cathode towards PCB **top** 
R1	1k Ω	Required	None
R2	100 Ω	Required	None
R3, R4	60 Ω	Required	None
R5	1.5k Ω	Optional	None
R6 - R9, R12	1k Ω	Optional	None
R10	10k Ω	Required	None
R11	33k Ω	Required	None
R13	3.3kΩ Resistor (1206 SMD)	Required	None
R14	1kΩ Resistor (1206 SMD)	Required	None

Component Identifier	Value	Required?	Orientation
S1, S2	N/A	Optional	None
SG1	5V	Optional	None
U1	SN65HVD233DR	Required	Package has small dimple in corner (pin 1) which is position to PCB **top** right edges
U2	ESP32 DevKitC-V4	Required	Position ESP32 development board's USB connector to PCB **right** edge
VR1	L7812CV	Optional	Heat sink towards top of board
VR2	LM2596-ADJ	Required	Fits only one way
VR3	LM1117-3V3	Required	Fits only one way
J11, J12	19-Pin	Required	None
ZD1	2.4V	Required	Cathode end has a white line and positioned towards PCB **right** edge

Testing and Verification

Card Configuration

1. If the LCC Fusion Node Card is at the end of the CAN Bus Network, set the CAN TERM selection to `TERMINATION` (single jumper caps positioned across the top 2 pins).
2. If the LCC Fusion Node Card is not at the end of the CAN Bus Network, set the CAN TERM selection to `No-Term` (2 jumper caps each positioned vertically on the left and right set of pins).

Visual Inspection

1. **Initial Check**: Examine the board for any obvious issues like missing components, solder bridges, or components that are misaligned or not fully seated.
2. **Solder Joint Inspection**: Use a magnifying glass or a microscope to inspect solder joints. Look for cold solder joints, insufficient or excessive solder, or any shorts between pads.
3. **Component Orientation**: the IC's are correctly oriented according to the PCB silkscreen or schematic.

Connectivity Testing

1. **Continuity Check**: Use a multimeter in continuity mode to check for shorts between power rails and ground, and to ensure there are no open circuits in critical connections.

Power Input/Output Tests

Power input and output testing ensures that voltage levels are accurate, components are properly placed, and connections remain continuous across the Node Card's power circuits. These tests verify the integrity of each power rail, helping identify any potential issues before installing sensitive components.

Perform each step below in sequence. When checking voltage (**V**), set a multimeter to **DC voltage** mode and measure across **V+** and **GND** connections. For continuity checks (** Ω**), switch the multimeter to** resistance** mode and measure both ends of the connection to confirm a low-resistance path.

> NOTE: Do not install the ESP32 until all voltages are verified to avoid potential damage.

> NOTE: If the expected results are not met, consider the following actions:
>
> 1. Re-verify the orientation of components listed in Pre-Reqs.
> 2. Check soldering for poor connections or solder bridges between SMD legs and PTH pins.
> 3. Temporarily remove optional components, such as protection diodes, to isolate the issue.
> 4. Replace the component with a known good equivalent if the issue persists.

Test Description	Pre-Reqs	Test Points	Expected Result
Verify GND Connection	None	`BATT` **GND** connection and `NODE BUS` **GND** pads	Ω0

Test Description	Pre-Reqs	Test Points	Expected Result
Verify Blown Fuse Indicator	1. Attach **>14V** power supply with circuit protection to `PWR IN` **ATX 5557** connector (J1, pins 1 and 2) 2. **Check for Hot Components**: Feel for overheating components	None	**Red LED1** fades in/out indicating blown (or no fuse in FH1) and `FUSE BYPASS` is not selected
Verify No Short Circuits	1. `FUSE BYPASS` (JP1) set to bypass the fuse using a Jumper Cap 2. `OUTPUT` (JP2) selection set to `INPUT` using a Jumper Cap 3. Verify orientation of protection diodes D1 and D9	`PWR OUT` (J4), across ATX 5557 **V+** (pin 1) and **GND** (pin 2)	1. **Red LED1** is not on 2. Match input voltage
Verify `POWER` Indicators	None	None	`POWER` indicators `3V3`, `5V`, `12V` (Green LEDs) are all **on**
Verify `PWR IN` Power Input Connections	1. `PWR IN` **USB-C** socket (J2) using V+ (pins 2, 3) and GND (pins 1,4) 2. `PWR IN` **DC-005** connector (J3) using V+/GND as labeled	`PWR OUT` (J4), across ATX 5557 **V+** (pin 1) and **GND** (pin 2) `NODE BUS` pads, across **12V** and **GND** pads	Match input voltage[13]
Verify `CAN BUS` Power Input Connections	Attach **>14V** power supply to each of the `CAN BUS` RJ45 sockets (J5/J6): V+ (pins 3,4) and GND (pins 7,8)	`NODE BUS` pads, across **12V** and **GND** pads	Match input voltage[1]
Verify `BATT` Power Input Connection	Attach **>14V** power supply to `BATT` (JST XH, Screw/Spring Terminal, J12) pins 1,2	`NODE BUS` pads, across **12V** and **GND** pads	Match input voltage[1]

Test Description	Pre-Reqs	Test Points	Expected Result
Verify 3A Fuse	1. Remove `FUSE BYPASS` selection 2. Install **1808 3A** fuse in fuse holder (FH1) 3. Attach power supply to one of the power input connectors	`PWR OUT` (J4), across ATX 5557 **V+** (pin 1) and **GND** (pin 2)	Match input voltage[1]
Verify `NODE BUS` 12V Pad	1. `OUTPUT` (JP2) selection set to `12V` using a jumper cap 2. Verify the orientation of the voltage regulator (VR1)	`NODE BUS` pads, across **12V** and **GND** pads	~11.5V[1]
Verify `NODE BUS` 5V Pad	1. Verify orientation of filter capacitors C5 and C6 2. Verify orientation of protection diode D10	`NODE BUS` pads, across **5V** and **GND** pads	~5V[2]
Verify `5V OUT` Connection	Verify the USB-C socket alignment and soldering	`5V OUT` USB-C (J9), across **V+** (pins 2,3) and **GND** (pins 1,4)	~5V[2]
Verify `NODE BUS` 3V3 Pad	Verify orientation of diode D8	`NODE BUS` pads, across **3V3** and **GND** pads	~3.3V[3]
Verify `CAN BUS` Termination	n/a	`CAN BUS` (J5/J6) **CAN-H** (pin 1) and **CAN-L** (pin 2)	>120 Ω[4]
Verify `IO DEVICES` Connection	n/a	`IO DEVICES` (J7) pins 1-8 and `NODE BUS` **GND** tab	0V

Footnotes:

1. **12V Pad Voltage Drop**: The expected output voltage is slightly lower than the input voltage (~0.5V) due to SS310 protection diodes.
2. **5V Pad Voltage Drop**: The 5V output voltage may show a minor variance from exactly 5V due to protective diode voltage drops.
3. **3V3 Pad Voltage Drop**: The 3V3 pad voltage may show a minor variance from exactly 3.3V due to protective diode voltage drops.

4. **open circuit (>120 Ω)**: When only one CAN network device (e.g. LCC Node) is on the network, no CAN Network termination resistor is applied by the auto-termination circuitry.

ESP32 Communications Testing

This section confirms the functionality of both **CAN Network** and **I2C Serial** communication components and connections on the Node Card. Before testing, ensure the ESP32 module is installed only after verifying the **5V** power supply is present.

Use a multimeter to check for expected voltage levels during each step, following the sequence outlined below. For each test:

- **Voltage checks**: Set the multimeter to **DC voltage** mode and measure across the designated test points.
- **Continuity checks** (if applicable): Use **resistance** mode to confirm a low-resistance path.

> **Note**: During testing, monitor the **Red LED** on the DevKit-C Module to confirm ESP32 power status.

Test Description	Pre-Reqs	Test Points	Expected Result
Verify ESP32 Module	1. Attach power supply to one of the power inputs 2. Verify **~5V** at ESP32 module (U2) across `Vin` and `GND` pins 3. Install DevKit-C Module (U2) while verifying orientation (USB connection position towards PCB **right** edge. Recommend using 19-Pin female headers for easy removal of the ESP32 module.	n/a	**Red LED** power indicator on the DevKit-C Module is **On**. (If not, verify orientation and check voltage at Vin.)
Verify `CAN BUS` Communication Connections	1. Verify CAN transceiver (U1) orientation 2. Verify Ferrite Bead (FB3) is soldered correctly 3. Verify ESD Diodes (D6, D7) are soldered correctly	1. `CAN BUS` (J5/J6) pins, **CAN-H** (pin 1) and **GND** (pin 3) 2. `CAN BUS` (J5/J6) pins, **CAN-L** (pin 2) and **GND** (pin 3)	~2.25V - 2.5V (both lines similar during idle state)

Test Description	Pre-Reqs	Test Points	Expected Result
Verify `CAN I/O` Communications Connection	1. Verify Ferrite Beads (FB5, FB6) are soldered correctly 2. Verify ESD Diode (D7) is soldered correctly	1. `CAN I/O` (J11) pins, **CAN-H** and **GND** 2. `CAN I/O` (J11) pins, **CAN-L** and **GND**	~2.25V - 2.5V (both lines similar during idle state)
Verify `NODE BUS` I2C Communications	1. Verify Ferrite Beads (FB3, FB4) are soldered correctly 2. Verify ESD Diode (D6) is soldered correctly	1. `NODE BUS` tabs, **SDA0** and **GND** 2. `NODE BUS` tabs, **SCL0** and **GND** 3. `NODE BUS` tabs, **SDA1** and **GND** 4. `NODE BUS` tabs, **SCL1** and **GND**	~3.3V (both lines similar during idle state)
Verify `CAN BUS` Termination	1. **Node Card** is not connected to the CAN network 2. Verify voltage comparator (U3) orientation 3. Verify Zener Diode (ZD1) orientation 4. Auto-termination components (U3,ZD1,Q1,Q2,R3,R4,C7) are soldered correctly	`CAN BUS` (J5/J6) pins, **CAN-H** (pin 1) and **CAN-L** (pin 2)	120Ω (when Node Card is the only device connected)
Verify `NODE REBOOT` Tactile Button	Press `NODE REBOOT` (S1) button once. When no button is installed, momentarily short pads 1 and 2 together	n/a	ESP32 power (RED) LED turns off and then on (indicating a reboot)

Node Card Auto Testing (Using Serial Monitor During Firmware Startup)

Test Description	Pre-Reqs	Expected Result
Verify Firmware Startup with Serial Monitor	1. Upload the 'LCC Node Card' firmware to the ESP32. 2. Attach power supply to any power input. 3. Insert DevKit-C Module (U2), ensuring the USB connection faces the **right** edge of the PCB. 4. Attach ESP32 to computer using USB cable. 5. Open serial console, set the **port** (e.g., COM3) and **baud rate** (`115200`).	**[I] LCC Node: Started** message is displayed
Verify Voltage To ESP32	After completing starting of firmware with serial monitor	**[W] Low Voltage from power supply to ESP32** message is **NOT** displayed
Verify 12V To NODE BUS HUB	After voltage test completion	**[W] Low Voltage from power supply to 12V** message is **NOT** displayed
Verify `NODE BUS` I2C Communications (BUS A, BUS B)	After voltage test completion	**[I] I/O Card Communications is working** message is displayed
Verify `NODE BUS` CAN Communications	After I2C communications test completion	**[I] Successfully connected to CAN Network** message is displayed
Verify `I/O DEVICES` Connectivity To Devices	After CAN communications test completion	**[I] Node Card I/O device found on connection nn** messages for each device connected to the `I/O Devices` connector

Node Card Testing (Using Serial Monitor Testing Program)

This table provides step-by-step instructions to verify the Node Card's communication interfaces and I/O DEVICES functionality using the serial monitor testing program. Follow each test in sequence, and check "Expected Result" to confirm each test's success.

Test Description	Pre-Reqs	Action	Expected Result
Verify Testing Firmware	1. Upload the 'Testing' firmware to the ESP32. 2. Attach power supply to any power input. 3. Insert DevKit-C Module (U2), ensuring the USB connection faces the right edge of the PCB. 4. Attach ESP32 to computer using USB cable. 5. Open serial console, set the **port** (e.g., COM3) and **baud rate** (`115200`).	Enter `m` in the serial console input and send.	`Main Menu - LCC Fusion Project` is displayed in the serial console.
Verify `NODE BUS` I2C Communications (BUS A and BUS B)	1. From the main menu, select `Node Management` by entering `1`. 2. Choose `Device Testing Management`. 3. Select `Test Node Card Connectivity`.	1. Connect `NODE BUS` tabs, `SDA0` and `SCL0` with a jumper wire. 2. Enter `c` to start the test. 3. Repeat by connecting a jumper wire to `NODE BUS` tabs, `SDA1` and `SCL1` and entering `c` to start the test again.	Displays **I2C Continuity Test Successful** message.

Test Description	Pre-Reqs	Action	Expected Result
Verify `NODE BUS` CAN Communications	After completing both I2C tests	1. Connect `NODE BUS` `CAN-H` and `CAN-L` (PCB bottom) with a jumper wire. 2. Enter `c` to start the test.	Displays **CAN Continuity Test Successful** message.
Verify `I/O DEVICES` Connectivity To Devices	After CAN test completion	1. Attach a multimeter or LEDs to `I/O DEVICES` pins 1-8 and `NODE BUS` `GND`. 2. Enter `c` to start test. Each pin will sequentially go HIGH (3.3V) for 0.5 sec, repeating until `s` is entered.	Multimeter reads 3.3V or LEDs light up, one at a time.

Troubleshooting

- See I2C Trouble Shooting.

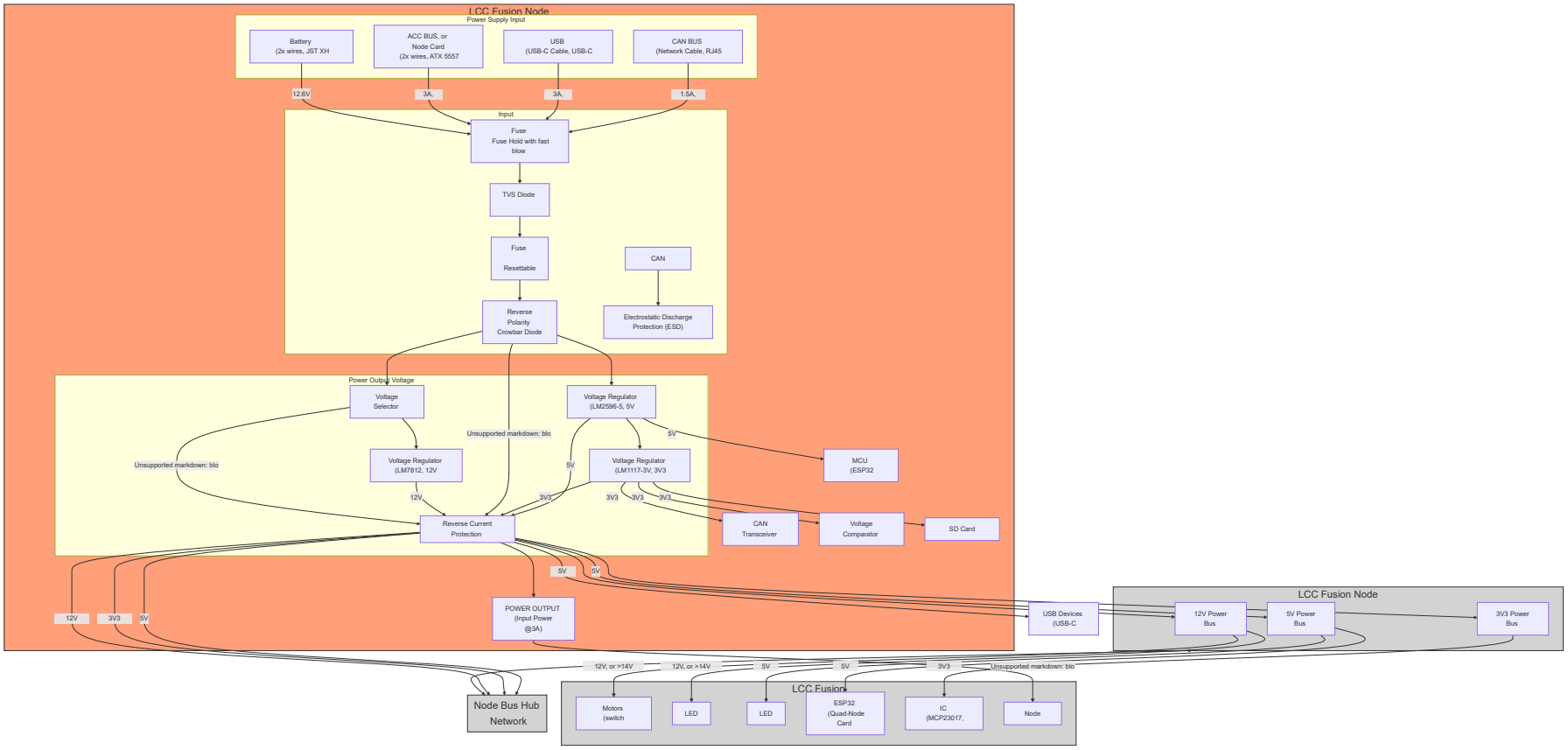
References

1. ESP32 DevKitC Module - 38Pin ESP32 DevKitC with ESP32-WROOM-32D
2. Node Card Firmware configuration:
    1. CAN bus @ 125kbs (per the NMRA LCC standard)
    2. SPI bus @ 4MHz
    3. **NOTE**: ESP32 PSRAM (SPIRAM) can not be used because pin conflicts with CAN bus (pin 5), I2C bus 1 (pin 18), and SPI (pins 19 and 23)
    4. Node Card ESP32 Pin Assignments

Node Card Function	GPIO Pin		Node Card Function	GPIO Pin
CAN TX	4		CAN RX	5

Node Card Function	GPIO Pin		Node Card Function	GPIO Pin
I2C SDA0 (BUS 0)	21		I2C SCL0 (BUS 0)	22
I2C SDA1 (BUS 1)	18		I2C SCL1 (BUS 1)	25
SPI CS	17		SPI SCK/CLK	26
SPI MOSI	23		SPI MISO	19
NODE REBOOT	EN/PU		CDI RESET	36
LOW 12V VOLTAGE DETECTION	39		LOW 3V3 VOLTAGE DETECTION	34
IO Pins 1-4 (Digital, ADC, PWM)	2, 12, 15, 14		IO Pins 5-8 (Digital, ADC, PWM)	13, 27, 32, 33
IO Pins (Touch Pads)	T2, T5, T3, T6		IO Pins (Touch Pads)	T4, T7, T9, T8
Flash Pins (reserved)	6, 7, 8, 9, 10,11		UART0 (reserved)	1, 3
Active Buzzer	35		Not Used (Input/Output)	0

3. Flow of current:


LCC Fusion Node
Power Supply Input
Battery
(2x wires, JST XH
ACC BUS, or
Node Card
(2x wires, ATX 5557
USB
(USB-C Cable, USB-C
CAN BUS
(Network Cable, RJ45
12.6V
3A
3A,
1.5A,
Input
Fuse
Fuse Hold with fast
blow
TVS Diode
Fuse
Resettable
CAN
Reverse
Polarity
Crowbar Diode
Electrostatic Discharge
Protection (ESD)
Power Output Voltage
Voltage
Selector
Voltage Regulator
(LM2596-5, 5V
Unsupported markdown: blo
Unsupported markdown: blo
Voltage Regulator
(LM7812, 12V
Voltage Regulator
(LM1117-3V, 3V3
5V
MCU
(ESP32
12V
3V3
3V3
3V3
3V3
Reverse Current
Protection
CAN
Transceiver
Voltage
Comparator
SD Card
5V
5V
12V
3V3
5V
POWER OUTPUT
(Input Power
@3A)
USB Devices
(USB-C
LCC Fusion Node
12V Power
Bus
5V Power
Bus
3V3 Power
Bus
12V, or >14V
12V, or >14V
5V
5V
3V3
Unsupported markdown: blo
Node Bus Hub
Network
LCC Fusion
Motors
(switch
LED
LED
ESP32
(Quad-Node
Card
IC
(MCP23017,
Node