Pi-EVCC

Overview of Plug-n-Play Electric Vehicle Charging Controller

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1. Overview

Pi-EVCC is a standalone off-the-shelf charging control unit designed by Pi Innovo to meet the requirements of an EVCC (Electric Vehicle Charging Controller).

Pi-EVCC controller is based on Pi Innovo's successful M560 (12V) and M580 (24V) units that provide integrated Vehicle Control Unit (VCU) and Vehicle Charge Control Unit (VCCU) functionality. The M560/M580 are certified ISO 26262 ASIL-D Safety Element Out of Context safety controllers.

Pi-EVCC is equipped with Powerline Communication (PLC) circuitry to enable charging. Thus, it is capable of interfacing with an off-board charging station, also known as EVSE (Electric Vehicle Supply Equipment).

Charging standards currently supported by Pi-EVCC include DIN SPEC 70121, SAE J1772, and SAE J2847-2. Support for ISO 15118 is in development, contact us for more details.

Pi-EVCC is delivered with charging control application software and the user has access to a number of calibration variables via a dedicated CAN bus to fine-tune the performance to match their system.

Pi-EVCC communicates with other ECUs in the vehicle via the CAN bus to provide the status of the charging session and receive information such as permission to start charging, battery state of charge, etc. Pi-EVCC also provides I/O for driving charging status LEDs, charging port lock, relays, Stop charging switch, etc.

2. System Configuration

2.1 Typical System Setup

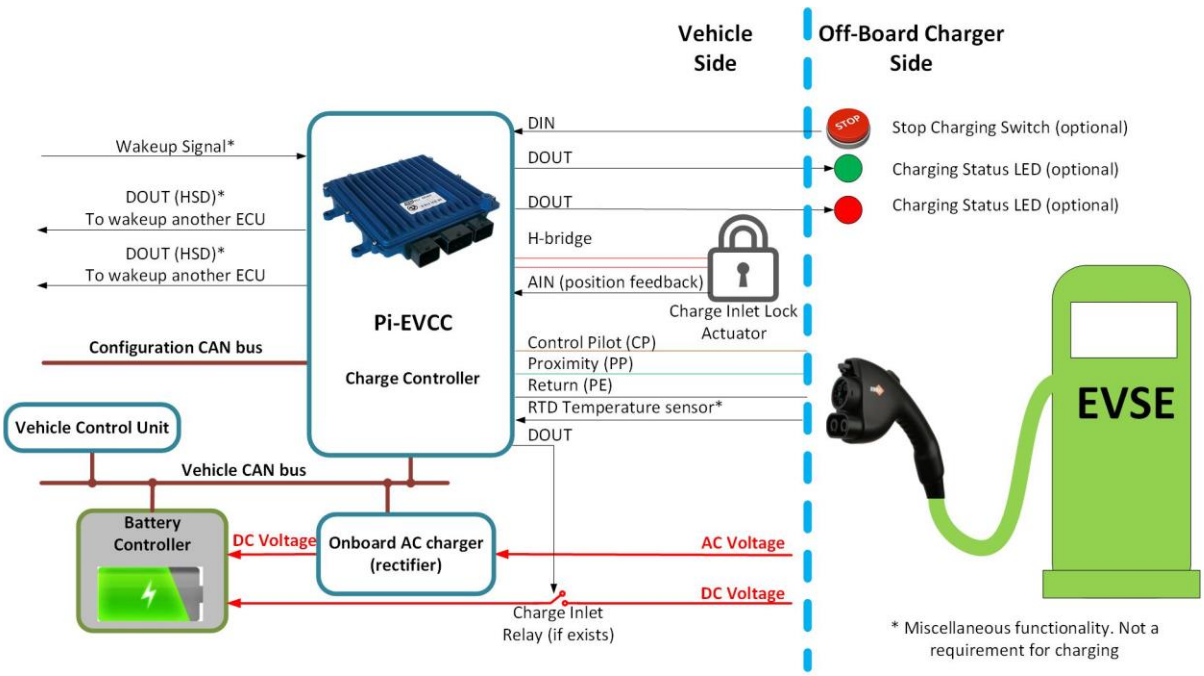

Figure 1:Typical vehicle configuration for using Pi-EVCC

2.2 Pi-EVCC Diagram (I/Os)

The following table lists the interfaces of Pi-EVCC and available diagnostics for each interface. The table also includes an overview of the type of diagnostics that is performed by Pi-EVCC. A detailed description of the diagnostics is provided in the User guide document, delivered as part of the customer deliverables.

Table 1: Summary of Pi-EVCC Interfaces

Interface	Specifications	Diagnostics	Notes
EVSE Interface	N/A	Invalid PP Invalid CP Invalid PLC signal, Invalid Sequence, Invalid Timing	Applies to the signals for Proximity Pilot (PP), Control Pilot (CP) and Powerline communication (PLC), respectively
Vehicle CAN bus	No Termination	Bus Off, Message Timeout, Message Error,	To communicate with other ECUs in the vehicle, broadcast charging session information, diagnostic information,

Interface	Specifications	Diagnostics	Notes
		Message Overrun, Invalid Message Counter Sequence, Invalid Signal range	receiving commands for starting/terminating the charge session, and actuating the I/O (if default I/O functions are disabled by configuration CAN bus) Default: 500K baud rate. Changing the baud rate requires reprogramming the ECU with the supplied HEX file for 250K, 500k, or 1M baud rates
Configuration CAN bus	120Ω Termination	None	UDS reprogramming Configuring I/O functionalities of Pi-EVCC Fixed 500K baud rate.
Sensor Supply Voltage (VREFB)	5V 250mA	Out of range	To be used for supplying custom 5V sensors such as the position sensor for Charge Inlet lock actuator
H-Bridge	5 A	Current Feedback Under voltage Over Temperature Over Current Open Load	Controllable via Vehicle CAN bus (may be used for driving an actuator); Default function: Actuating the charging interlock
Digital Output LSD 1	3.2 A	Short to battery Open load	Controllable via Vehicle CAN bus (may be used for driving an actuator such as HV relay) Default function: High Voltage Relay 1
Digital Output LSD 2	2.2 A	Short to battery Open load	Controllable via Vehicle CAN bus (may be used for driving an actuator such as HV relay) Default function: High Voltage Relay 2
Digital Output LSD 3	2.2 A	Short to battery Off Open load	Controllable via Vehicle CAN bus (may be used for driving LED indicator, Relay) Default function: None
Digital Output LSD 4	2.2 A	Short to battery Off Open load	Controllable via Vehicle CAN bus (may be used for driving LED indicator, Relay)

Interface	Specifications	Diagnostics	Notes
			Default function: LED Indicator 1
Digital Output LSD 5	700 mA	Short to battery Short to ground Off Open load Under Voltage	Controllable via Vehicle CAN bus (may be used for driving LED indicator, Relay) Default function: LED Indicator 2
Digital Output HSD 1	700 mA	Over Current On Open load	Controllable via Vehicle CAN bus (may be used for driving LED indicator, Relay, or Waking up another ECU); Default function: Wakeup another ECU once charger is plugged in.
Digital Output HSD 2	700 mA	Over Current On Open load	Controllable via Vehicle CAN bus (may be used for driving LED indicator, Relay, or Waking up another ECU); Default function: Wakeup another ECU once charger is plugged in.
Digital Input 1	1KΩ to VREFB	None	Manual Charge Stop Switch for 0 to 5V switch
Digital Input 2	10KΩ to battery	None	Manual Charge Stop Switch for 0 to Battery voltage switch
Digital Input	N/A	None	Ignition Signal to wakeup Pi-EVCC
Analog Input 1	1KΩ to 5V	Out of range Slew rate high	To measure the temperature at the charge inlet for AC charging This input is populated with standard circuit with pull-up bias, with an accuracy of ±2°C and resolution of 1°C over the temperature range -40°C to +150°C.
Analog Input 2	1KΩ to 5V	Out of range Slew rate high	To measure the temperature at the charge inlet for DC charging This input is populated with standard circuit with pull-up bias, with an accuracy of ±2°C and resolution of 1°C over the temperature range -40°C to +150°C.
Analog Input 3	1KΩ to 5V	Out of range Slew rate high	To measure the temperature at the charge inlet for DC charging

Interface	Specifications	Diagnostics	Notes
Analog Input 4			This input is populated with standard circuit with pull-up bias, with an accuracy of ±2°C and resolution of 1°C over the temperature range -40°C to +150°C.
	10KΩ to battery Range: 0V to battery voltage	Out of range Slew rate high	To measure the position of the charge inlet lock actuator If the position is Boolean (Lock/Unlock) this input may still be used. However, the diagnostics need to be disabled via the Configuration CAN bus

3. Pi-EVCC I/O Description

Pi-EVCC provides the required I/O for managing a charge session. Additional I/O are available that may be configured to perform a predefined task, or controlled by CAN messages.

3.1 EVSE Interface and AC/DC charging control

Pi-EVCC is equipped with a built-in charging circuitry. This allows Pi-EVCC to directly interface with the EVSE via Control Pilot (CP), Proximity Pilot (PP), and Pilot Shield signals. In addition, the Powerline Communication (PLC) modem in Pi-EVCC and OpenECU platform software allows for digital communication between the EVSE and Pi-EVCC software.

Once the charger is plugged in to the vehicle, Pi-EVCC identifies the status of the charging plug and the type of charging mode.

The high-level functions of Pi-EVCC are as follows:

- Obtain instruction to start charging from another ECU in the vehicle via CAN bus.
- Identify connection with Charge plug
- Perform diagnostics on CP and PP signals
- Perform diagnostics on all CAN communications with the vehicle
- Perform diagnostics on the additional I/O that is configured for use
- Obtain battery information (such as SOC, voltage, desired charging current) periodically over CAN
- Monitor state of the Charge stop switch

In addition to the above functions, for AC charging the following conditions are verified:

- Periodically monitor the voltage and current of AC line.

And for DC charging:

- Verify compatibility with the EVSE maximum voltage
- Verify "no faults" are detected during digital communication with EVSE

3.2 Vehicle CAN bus:

The Vehicle CAN is the main interface CAN bus for communication between Pi-EVCC and other ECUs in the vehicle. On this CAN bus, Pi-EVCC broadcasts information such as the charging plug status, the charging mode and phase, reasons for unexpected termination of the charging session, the measured DC current/voltage by EVSE, etc. In addition, Pi-EVCC will send requests that need to be addressed by other ECUs in the vehicle, such as request for inhibiting High Voltage Isolation Monitoring on the vehicle side.
Pi-EVCC expects to periodically receive messages that contain information such as the permission to start charging, battery state of charge, maximum voltage, desired charging current, HV Isolation status, etc.
Furthermore, this CAN bus may be used to control Pi-EVCC I/O such as actuating the HV relays on the charging path. See Table 1 for the available diagnostics for communications on this CAN bus.

By default, the baud-rate for this CAN bus is 500k. If a different baud-rate is desired, then Pi-EVCC must be reprogrammed with a different HEX file. Pi Innovo will provide this HEX file, per customer's request. A CAN dbc file will be provided by Pi Innovo that contains the defined messages and signals. The message IDs may be modified by request only.

3.3 Configuration CAN bus

The Configuration CAN supports UDS reprogramming and CCP monitoring. In addition, via CAN communications on this bus, it is possible to enable or disable optional functionality of Pi-EVCC I/O.
A CAN dbc file will be provided by Pi Innovo that defines all available configurations via Configuration CAN bus. Once a CAN message is sent on Configuration CAN for changing an I/O functionality, that change will be saved in the NVM memory of Pi-EVCC. As a result, the configuration of Pi-EVCC only needs to be done once.

3.4 Locking system

At a certain stage of a charging session, the High Voltage (HV), sourced by EVSE, becomes present at the EV charge inlet. Thus, the EV must be equipped with a locking mechanism at the charging inlet to prohibit driver from disconnecting the charging cable while high voltage is present. For DC charging, such a locking mechanism is mandatory.
Pi-EVCC is equipped with a H-Bridges that is suitable for a variety of locking actuators. Using the built-in current feedback, Pi-EVCC has the ability to limit the H-Bridge current for protecting the actuator with regard to its maximum current rating. Alternatively, via Configuration CAN bus, it is possible to disable the closed-loop current control and instead, set a desired dutycycle for the H-Bridge.
Pi-EVCC has an analog input for position feedback from the locking actuator. If the feedback is a digital signal, this analog input may still be used for detecting the position.
Depending on current and position feedback, a decision will be made on whether the locking or unlocking operation has been successful. If Pi-EVCC identifies a failure on locking operation, it will terminate the DC charging session and broadcast the failure reason over the Vehicle CAN bus. However, the AC charging session may still be continued even if the locking operation fails (the failure will still be reported on the Vehicle CAN bus).

The default functionality of this H-Bridge for controlling the locking mechanism may be disabled through Configuration CAN bus. In that case, another ECU in the vehicle will be responsible for controlling this H-Bridge via the Vehicle CAN.

3.5 Digital outputs for Charging Relays

Pi-EVCC is equipped with a host of digital outputs (low-side, H-Bridges, PWM outputs). By default, Pi-EVCC energizes selected outputs (to close HV relays) when the pre-charging phase for DC charging is completed. At the end of charging session, when the DC charging current drops to 0A, the digital outputs are deenergized to open HV relays. This default functionality may be disabled by the user by sending appropriate instructions via CAN. In that scenario, these digital outputs will be energized and deenergized per received commands over Vehicle CAN bus.

Pi-EVCC, by default does not perform relay weld-checking. At the end of a DC charging session, an optional phase exists when the EV vehicle system can perform a relay weld-checking operation. During this phase, the digital outputs will be only energized and deenergized per received CAN commands from the vehicle system. In addition, during this phase, Pi-EVCC reports the measured voltage by the EVSE to the EV vehicle system via Vehicle CAN. Knowing the voltage on the EVSE side and having control over the Relays status gives the EV vehicle system the required freedom to execute the relay weld-checking operation.

3.6 Temperature sensors

During the charge session, the charging current needs to be reduced (or set to 0A) if the temperature at the charge inlet rises to an unacceptable level. This unacceptable level can be set by the configuration CAN bus.

PI-EVSS has 3 analog inputs for connecting thermistor sensors. These analog inputs have the standard circuit with pull-up bias, with an accuracy of ±2°C and resolution of 1°C over the temperature range -40°C to +150°C.

3.7 Charge Stop Switch

For DC charging, the EVSE typically has a user-interface that allows the user to terminate the DC charging session before the battery is fully charged. In addition to this mechanism, Pi-EVCC has two digital inputs for two optional "Charge Stop Switch" to be installed on the EV.

If the user decides to install these optional switches in the EV, then pressing any of these switches leads to terminating the charging session (both AC and DC) and unlocking the charge inlet lock by Pi-EVCC.

Note that for AC charging, pressing the latch on the charging plug is enough for terminating the charge session. However, in DC charging, pressing the connector latch is not possible due to the locking mechanism.

3.8 Miscellaneous Digital Outputs

These outputs have a variety of different current ratings suitable for applications such as LED indicators, actuating a relay, or waking up other ECUs, depending on the vehicle system design. All these outputs are controllable by CAN signals over the Vehicle CAN bus.

For instance, it is possible that the vehicle is parked, and the ignition is off and thus, ECUs such as the vehicle controller or the battery control module are in sleep mode. Once the EVSE connector is plugged in, Pi-EVCC wakes up by the Control Pilot signal. However, Pi-EVCC needs battery information and permission from the vehicle to start the charging session. As a result, some of HSD digital outputs of Pi-EVCC may be used to wakeup the necessary ECUs in the vehicle for charging control.

Some of digital outputs have default functionalities as listed in Table 1. For instance, some of HSD outputs when asserted, will wakeup other ECUs in the vehicle when EVSE is plugged in. In addition, some digital outputs are assigned for LED indicators with variety of different pre-defined signaling functions. It is possible to disable these default functionalities via Configuration CAN and allow an ECU in the vehicle to directly control the Pi-EVCC digital outputs over the Vehicle CAN bus.

3.9 Pi-EVCC Wake up Sources

Pi-EVCC has the following wakeup sources:

Table 2: Pi-EVCC wakeup sources

Wakeup Source	Note
Control Pilot	Control Pilot is one of the signals in an EV-EVSE interface. Once the EVSE connector is plugged in to the EV charge inlet, the voltage on Control Pilot wakeup Pi-EVCC
Ignition	This is an optional wakeup source which allows one of ECUs in the vehicle (or a switch) to wakeup Pi-EVCC. Using this wakeup source is optional. However, for configuring Pi-EVCC over the Configuration CAN bus, using this wakeup source is required.
Wake on CAN	The Pi-EVCC can also be woken up by presence of CAN traffic on CAN A and CAN B. In addition to generic CAN traffic, CAN A can be setup to wake the Pi-EVCC on receipt of a specific CAN message ID.

4. Customer Deliverables

- Pi-EVCC controller (12V or 24V options)
- Pi-EVCC pigtail harness
- Pinout document
- CAN dbc file
- User guide document
- A HEX file, per customer's request only, for reprogramming Pi-EVCC to change the default baud rate of Vehicle CAN bus

5. Abbreviations

CAN	Controller Area Network
CP	Control Pilot
dbc	CAN Database File
ECU	Electronic Control Unit
EVCC	Electric Vehicle Charging Controller
EVSE	Electric Vehicle Supply Equipment (A.k.a. off board charging station)
HSD	High Side Drive
HV	High Voltage
LSD	Low Side Drive
NVM	Non-Volatile Memory
OOR	Out of Range
PLC	Powerline Communication
PP	Proximity Pilot
PWM	Pulse Width Modulation
VCU	Vehicle Control Unit