E-P-206 Fuel Cell Control Board

# Features

* High Performance 32 bit AVR Fuel Cell Controller
* 10x 500mA 12V High Power Driving Outputs
* Dual CAN headers with separated CAN Fuel Cell Expansion Header
* USB Debug Port
* JTAG Programming interface with OCD
* 512 KB Flash/64KB RAM
* Programming time < 1 hour

# Table of Contents

1 Features 1

2 Table of Contents 2

3 Introduction 4

4 High Power Outputs with ESTOP (HPO) 5

4.1 ESTOP/SYSOK Module 5

5 General Purpose Input/Output (GPIO) 5

5.1 Analog IO 5

5.2 Digital IO 5

5.2.1 GPIO Pin Functionalities 6

5.4 FCC Inputs 7

5.4.1 START 7

5.4.2 SYSOK 7

5.4.3 TANKPRES 7

5.4.4 FCPRES 7

5.4.5 FAN1/FAN2 8

5.4.6 SERVO1/SERVO2 8

5.4.7 FCCURR 8

5.4.8 FCCON/VOLT 8

5.4.10 CAPCURR 9

5.4.11 CAPCON/VOLT 9

5.4.12 RESCON 9

5.4.13 THERMISTORS 9

5.4.14 JTAG 10

5.4.15 EXT-LEDS 10

5.4.16 CAN-EXP 10

5.4.17 CAN ETHERNET 11

5.4.18 POWER 11

6 Atmel AT32 UC3C1 MCU 12

6.1 CAN Interface 12

6.1.1 Vehicle CAN Interface 12

6.1.2 FCC Expansion CAN Interface 12

7 JTAG Interface with OCD 12

8 Revisions 13

8.1 Revision A: Initial Datasheet for E-P-206-R1.1 13

# Introduction

The EcoCar E-P-206 Fuel Cell Control Board (FCCB) is a purpose built Controller on a Chip (CoC). It is specifically designed for all of the inputs and sensors required to run a Ballard **XXXX** Fuel Cell. The controller is based around a 32bit Atmel AVR Automotive Grade Microcontroller (MCU).

# High Power Outputs with ESTOP (HPO)

The high power outputs on the device are each rated to 500mA/channel at 12V.

## ESTOP/SYSOK Module

The estop module ensures that all output signals are hardware ANDed with the SYSOK signal. When a logical 1 is present on the channel all outputs can be controlled normally and the controller runs as expected. When a logical 0 is applied to this input all high power outputs are forced off.

A logical 0 on the SYSOK module will also cause the controller itself to go into shutdown mode, and will require that SYSOK return to 1 and the START signal be given before the controller will restart.

# General Purpose Input/Output (GPIO)

## Analog IO

At the input pins of the AT32UC3C1 analog inputs must be in the range of 0-3V (with respect to ground). Therefore all inputs signals (which are assumed to be either 12V or 5V) are voltage divided before the input to the device. It is important that an over-voltage condition not be generated as this may harm the MCU.

## Digital IO

The FCCB provides 16 unused digital IO pins at screw terminals, although two of these signals are used for fan and servo PWM. On the remaining 14 pins the following functionalities are available, in addition to GPIO:

* PWM
* SPI
* USART
* CAN

See table 5.2.1 for all available functions and pin mappings.

### GPIO Pin Functionalities

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **GPIO Pin** | **MCU PIN** | **GPIO function** | | | | | |
| **A** | **B** | **C** | **D** | **E** | **F** |
| **1** | PC07 | PEVC - PAD\_EVT [2] | EBI - NCS[3] | USART2 - RTS | TC0 - B2 | TWIMS2 - TWCK | TWIMS1 - TWALM |
| **2** | PC11 | **IN USE (SERVO CONTROL PWM)** | | | | | |
| **3** | PC12 | (IN USE) | CANIF - TXLINE[1] | EBI - ADDR[20] | USART2 - CLK |  |  |
| **4** | PC13 | **IN USE (FAN CONTROL PWM)** | | | | | |
| **5** | PC14 | (IN USE) | USART0 - CLK | EBI - SDCKE | USART0 - CTS |  |  |
| **6** | PC15 | PWM - PWMH[1] | SPI0 - NPCS[0] | EBI - SDWE | USART0 - RXD | CANIF - RXLINE[1] |  |
| **7** | PC16 | PWM - PWML[1] | SPI0 - NPCS[1] | EBI - CAS | USART0 - TXD | CANIF - TXLINE[1] |  |
| **8** | PC17 | PWM - PWMH[0] | SPI0 - NPCS[2] | EBI - RAS | IISC - ISDO |  | USART3 - TXD |
| **9** | PC18 | PWM - PWML[0] | EIC - EXTINT[5] | EBI - SDA10 | IISC - ISDI |  | USART3 - RXD |
| **10** | PC19 | PWM - PWML[2] | SCIF - GCLK[0] | EBI - DATA[0] | IISC - IMCK |  | USART3 - CTS |
| **11** | PC20 | PWM - PWMH[2] | SCIF - GCLK[1] | EBI - DATA[1] | IISC - ISCK |  | USART3 - RTS |
| **12** | PC21 | PWM - EXT\_ FAULTS[0] | CANIF - RXLINE[0] | EBI - DATA[2] | IISC - IWS |  |  |
| **13** | PC22 | PWM - EXT\_ FAULTS[1] | CANIF - TXLINE[0] | EBI - DATA[3] |  | USART3 - CLK |  |
| **14** | PC23 | QDEC1 - QEPB | CANIF - RXLINE[1] | EBI - DATA[4] | PEVC - PAD\_EVT [3] |  |  |
| **15** | PC24 | QDEC1 - QEPA | CANIF - TXLINE[1] | EBI - DATA[5] | PEVC - PAD\_EVT [4] |  |  |
| **16** | PC31 | SPI0 - NPCS[3] | TC1 - B0 | EBI - DATA[12] | PEVC - PAD\_EVT [5] | USART4 - CLK |  |

## FCC Inputs

See below for a listing of all input connectors to the FCCB, and their parameters.

### START

The START signal triggers the Fuel Cell Controller to go into its startup mode.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | 5V |  | | |
| **2** | START | PB3 | 5V | Pulled down to GND. |

### SYSOK

The SYSOK signal indicates that the system is in proper operating condition. It should be shorted to ground in case of an emergency stop event such as an emergency stop button press, or unsafe hydrogen level.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | GND |  | | |
| **2** | SYSOK | PB2 | 5V | Pulled down to GND. |

### TANKPRES

The TANKPRES signal indicates the pressure in the line from the hydrogen tank.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | GND |  | | |
| **2** | S- | PA4 | 12V | Unused. Analog input. |
| **3** | S+ | PA5 | 12V | Attached to S- with 10k res. Analog input. |
| **4** | 12V |  |  |  |

### FCPRES

The FCPRES signal indicates the hydrogen pressure at the input to the fuel cell.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | GND |  | | |
| **2** | S- | PA6 | 12V | Unused. Analog input. |
| **3** | S+ | PA7 | 12V | Attached to S- with 10k res. Analog input. |
| **4** | 12V |  |  |  |

### FAN1/FAN2

The FAN1/FAN2 outputs are outputs to the two fan signals in the FCC enclosure.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | 12V |  |  |  |
| **2** | FAN\_OP | PC13 | 5V | PWM output to the fan. |
| **3** | FAN\_TAC | PD2 | 5V | Fan Tachometer, connected only to FAN1. |
| **4** | GND |  | | |

### SERVO1/SERVO2

The FAN1/FAN2 outputs are outputs to the two fan signals in the FCC enclosure.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | GND |  |  |  |
| **2** | SRV\_OP | PC11 | 5V | PWM output to the enclosure fan servo. |
| **3** | 5V |  |  |  |

### FCCURR

The FCCUR current sensor reports the current flowing from the Fuel Cell.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | 5V/3V |  |  | Selectable 5V/3V supply. Apply solder jumper on JP3 to select. |
| **2** | GND |  |  |  |
| **3** | FCCUR | PA9 | 5V/3V | Analog input. |

### FCCON/VOLT

This connector carries two signals: a TTL level signal that indicates if the fuel cell is connected, and a second that indicates the fuel cell voltage.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | FCVOLT | PA11 | 50V | 50V -> 3V voltage divider. |
| **2** | FCCON | PB23 | 5V | Pulled to ground. |
| **3** | 5V |  |  |  |

### CAPCURR

The CAPCUR current sensor reports the current flowing into or out of the ultra capacitors.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | 5V/3V |  |  | Selectable 5V/3V supply. Apply solder jumper on JP1 to select. |
| **2** | GND |  |  |  |
| **3** | CAPCUR | PA8 | 5V/3V | Analog input. |

### CAPCON/VOLT

This connector carries two signals: a TTL level signal that indicates if the ultra capacitors are connected, and a second that indicates the ultra capacitor voltage.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | CAPVOLT | PA10 | 50V | 50V -> 3V voltage divider. |
| **2** | CAPCON | PC0 | 5V | Pulled to ground. |
| **3** | 5V |  |  |  |

### RESCON

The RESCON signal indicates whether the start-up power resistors are connected.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | 5V |  | | |
| **2** | RESCON | PB 22 | 5V | Pulled down to GND. |

### THERMISTORS

This connector carries various thermistor readings, as well as the mass flow measurement.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | AMBTEMP4 | PA25 | 5V | Analog input. Forms voltage divider. |
| **2** | GND |  |  |  |
| **3** | AMBTEMP3 | PA24 | 5V | Analog input. Forms voltage divider. |
| **4** | GND |  |  |  |
| **5** | AMBTEMP2 | PA23 | 5V | Analog input. Forms voltage divider. |
| **6** | GND |  |  |  |
| **7** | AMBTEMP1 | PA22 | 5V | Analog input. Forms voltage divider. |
| **8** | GND |  |  |  |
| **9** | FCTEMP2 | PA21 | 5V | Analog input. Forms voltage divider. |
| **10** | GND |  |  |  |
| **11** | FCTEMP1 | PA20 | 5V | Analog input. Forms voltage divider. |
| **12** | GND |  |  |  |
| **13** | MFLOW | PA19 | 5V | Analog input. |
| **14** | GND |  |  |  |

### JTAG

The JTAG connector provides programming and debugging through the OCD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | TCK | PA0 | 5V |  |
| **2** | GND |  |  |  |
| **3** | TDO | PA2 | 5V |  |
| **4** | VREF |  | 5V |  |
| **5** | TMS | PA3 | 5V |  |
| **6** | SRST | N\_RESET | 5V | Pulled to VCC. |
| **7** | VCC |  | 5V |  |
| **8** | TRST |  | 5V | Unused. Pulled to VCC. |
| **9** | TDI | PA1 | 5V |  |
| **10** | GND |  |  |  |

### EXT-LEDS

This connector provides a breakout to a separate board containing four status LEDs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | VCC |  |  |  |
| **2** | GND |  |  |  |
| **3** | LED0 | PB21 | 5V |  |
| **4** | LED1 | PB30 | 5V |  |
| **5** | LED2 | PB19 | 5V |  |
| **6** | LED3 | PB20 | 5V |  |

### CAN-EXP

This connector carries the FCC CAN Expansion Interface, and is capable of sourcing small amounts of power to connected expansion boards.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | VCC |  | 5V | CAN supply up to 500mA to expansion boards. |
| **2** | CAN\_N |  | 5V | Negative CAN differential pair. |
| **3** | CAN\_P |  | 5V | Positive CAN differential pair. |
| **4** | GND |  |  |  |

### CAN ETHERNET

The CAN ETHERNET connector is a dual Ethernet header that provides a connection the Vehicle CAN Network. Each connector has the same pinout as below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1** | CAN\_P |  | 5V | Positive CAN differential pair |
| **2** | CAN\_N |  | 5V | Negative CAN differential pair. |
| **3** |  |  |  |  |
| **4** |  |  |  |  |
| **5** |  |  |  |  |
| **6** | 12V |  | 12V |  |
| **7** | 5V |  | 5V |  |
| **8** | GND |  |  |  |

### POWER

The power connector provides all of the power to the FCCB from the FC Power Board (E-P-204). This connector is designed such that the power board can be stacked vertically above or below the FCCB and directly connected through the header.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Connector**  **Pin** | **Function** | **MCU Pin** | **Voltage Rating** | **Notes** |
| **1-6** | 12V |  | 12V |  |
| **7-13** | GND |  |  |  |
| **14** | FC\_PWR\_GOOD | PC6 | 5V | Signal to indicate that the fuel cell power is good – enabling the power board to run off of fuel cell power. |
| **15-16** | 5V |  | 5V |  |

# Atmel AT32 UC3C1 MCU

The FCCB is powered by an Atmel AT32UC3C1 automotive grade MCU. This MCU performs all of the processing and control for the fuel cell. It is equipped with a large RAM and Program Space, and is specifically made for automotive applications. The MCU also contains two separate CAN ports, and a USB interface.

## CAN Interface

The AT32UC3C1 contains two separate CAN interfaces, consisting of CAN TX and RX signals. These signals are fed into a Microchip MCP2551 CAN Transceiver, which turns the TX and RX signals into a differential pair. This is necessary as the MCU is not capable of driving the CAN connections at high speed over a length connection, and would suffer significant interference.

### Vehicle CAN Interface

The vehicle CAN interface provides the FCCB with a CAN network connection with the vehicle, and is used for outputting general fuel cell parameters which are used by the vehicle base station and other car components to run the vehicle. This interface using the CAN[0] interface on the AT32UC3C1.

### FCC Expansion CAN Interface

The controller provides a secondary CAN network which can be optionally used to interface with new expansions to the controller. This interface consists of a GND and a CAN differential pair to be connected to optional peripherals such as additional GPIO.

# JTAG Interface with OCD

The FCCB is equipped with an industry standard JTAG programming interface with On-Chip Debug (OCD) system. This allows the controller to be programmed and execution to be step through using the standard Atmel Studio 6 IDE.

# Revisions

## Revision A: Initial Datasheet for E-P-206-R1.1

**By:** Michael Blouin

**Date:** March 30, 2015

Initial revision for the first run of E-P-206-R1.1 – final draft.