ALL Power Labs
personal scale power

Chapter 4
Automation Assembly

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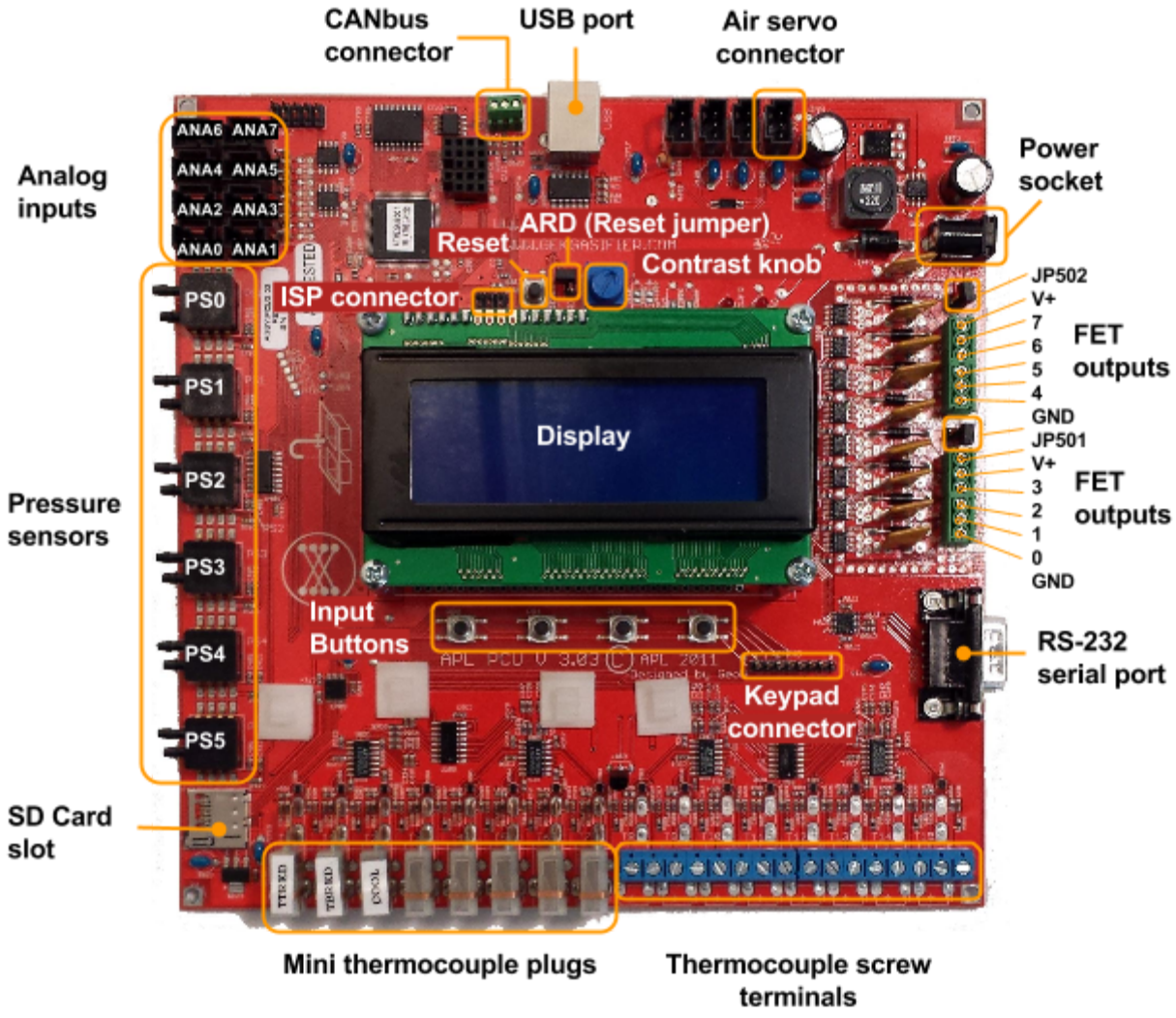
Process Control Unit (PCU)

Introduction

The PCU is a printed circuit board (PCB) that serves as the digital control unit that automates and provides data logging for the Power Pallet. The PCU's processor is an *Atmel ATmega1280*, the 8-bit RISC microcontroller of the AVR family. The PCU receives data from sensors mounted on the Power Pallet through its input channels and commands the subsystems through its outputs to the relay board, which is mounted underneath it.



PCU Power Cable

The PCU converts the 12V DC input power, provided by the on-board battery, to 5V DC and 3.3V DC for most of its components.

Display and input controls

The PCU displays information on a 4-row, 20-column text screen, which accepts user input from the keypad on the front panel, or through the four input buttons directly below the display on the PCB.

Analog Inputs

The PCU has 8 analog input (ANA) channels that enable it to sense variable-voltage signals that indicate the state of the Power Pallet's subsystems. Each channel reads a voltage from 0 to 5V, which is then converted to a proportional 10-bit digital value in the range of 0 to 1023. For example, 2.5V, which is halfway between 0 and 5V, would be read as a value of 511, which is halfway between 0 and 1023.

The PCU's analog inputs are ordered as follows:

ANAs *from Relay Board to PCU*			
ANA0	O_2 Sensor Signal (Lambda)	**ANA4**	Auger Current
ANA1	Fuel Switch	**ANA5**	Throttle Position (since 11/2013)
ANA2	Key Switch	**ANA6**	*Coolant (Not Used)*
ANA3	Engine Oil Pressure	**ANA7**	Ash auger motor driver 5V DC power output (to driver PCB) and current sense input (from driver)

FET Outputs

The 8 Field Effect Transistor (FET) outputs from the PCU are connected open-drain circuits that control electromechanical relays. When on, each FET provides a connection to ground. When off, no connection is made.

The FETs are wired to the Power Pallet's subsystems as follows:

FETs *from PCU to Relay Board*			
FET 0	Fuel auger forward	**FET 4**	Flare ignitor
FET 1	Grate shaker	**FET 5**	O2 sensor reset
FET 2	Engine ignition	**FET 6**	Alarm
FET 3	Engine starter	**FET 7**	Fuel auger reverse

Thermocouple Connectors

The PCU's T0–T6 thermocouple connections are K-type mini thermocouple plugs, and connections T7–T14 are K-type screw terminal connections. The thermocouple that measures the gas temperature at the reactor's hearth restriction is connected to T0 and displayed as **`Trst`**, the thermocouple measuring the gas temperature of the end of the reduction zone (at the top of the grate basket) is connected to T1 and is displayed as **`Tred`**, and the thermocouple measuring the engine's coolant temperature is connected to T2. Additional thermocouple connections are available for user-customized operation and firmware.

Table of Thermocouples

Display Variable:	`Trst`	`Tred`	`Tcoolant`
Abbreviation of:	**T**emperature at the **res**triction	**T**emperature of **red**uction	**T**emperature of **coolant**
Specific Location	Inside a steel sleeve; measures under the restriction of the hearth	Inside a steel sleeve; measures at the top of the grate basket	Top of engine coolant circuit, before coolant enters radiator.
PCU Port	T0	T1	T2
Thermocouple Specs	K-type, 1/16" dia. x 24" L	K-type, 1/16" dia. x 24" L	K-type Pipe Plug Probe ¼" dia

Differential Pressure Sensors

Two ranges of pressure can be measured by the PCU's pressure sensors: P0-P3 can sense +/- 28 inches of water (7 kPa); P4 & P5 can sense +/- 8 inches of water (2 kPa).

Display variable:	`Pcomb`	`Preact`	`Pfilt`
Abbreviation of:	**P**ressure at the **comb**ustion zone	**P**ressure of the **react**or	**P**ressure at the **filt**er
Specific Location	Reading taken at the top of ignition tube, which leads to the top of the combustion zone. See Annotated Figure D.	Reading taken at the gas outlet from the reactor right before it enters the cyclone.	Reading taken at the top of the filter.
PCU barb	P2	P0	P1

Note: Pressure lines should be connected to the top barb of each sensor. The bottom barb must remain open to the atmosphere.

Calibrating the Pressure Sensors

Pressure sensors should be re-calibrated if the zero-point drifts or when the PCU is first used. You calibrate the pressure sensors through the following process:

1. Remove the pressure tubing from the barbs on the PCU's pressure sensors.
2. Turn on the Power Pallet.
3. Scroll through the menus (by pressing next) until you reach the screen that says "Calibrate Pressure Sensors to Zero?"
4. Choose "Yes."
5. Push the pressure tubing onto the barbs on the PCU's pressure sensors.
    a. Make sure that the each tube is connected to the correct/corresponding sensor.
    b. Make sure that the pressure tube is attached to the top/front barb on each sensor and that the back/lower barb is exposed to the atmosphere.
    c. Make sure that the tubing is pushed all the way down so that it contacts the square body of the sensor.

ARD Jumper Settings

- The **ARD** jumper must be set (both pins connected) in order to communicate with the PCU through the USB serial connection. When the **ARD** jumper is set, any serial connection to the PCU will reset it; therefore, we recommend that the jumper remain unset (connected to one pin only) during normal operation of the Power Pallet. (ARD stands for Arduino, the type of microcontroller used on the PCU.)
- Jumpers **JP501** & **JP502** enable voltage clamping diodes and should be left unset during normal operation.

Firmware Upload

The Arduino firmware program is installed on the PCU and provides the automated control logic for the Power Pallet. Each Power Pallet is shipped with firmware installed; however, reprogramming may be necessary to update the code to the latest version or if the PCU has been replaced. Instructions to reprogram the PCU are below. Remember, the ARD jumper must be connected to reprogram the Power Pallet.

You will need:

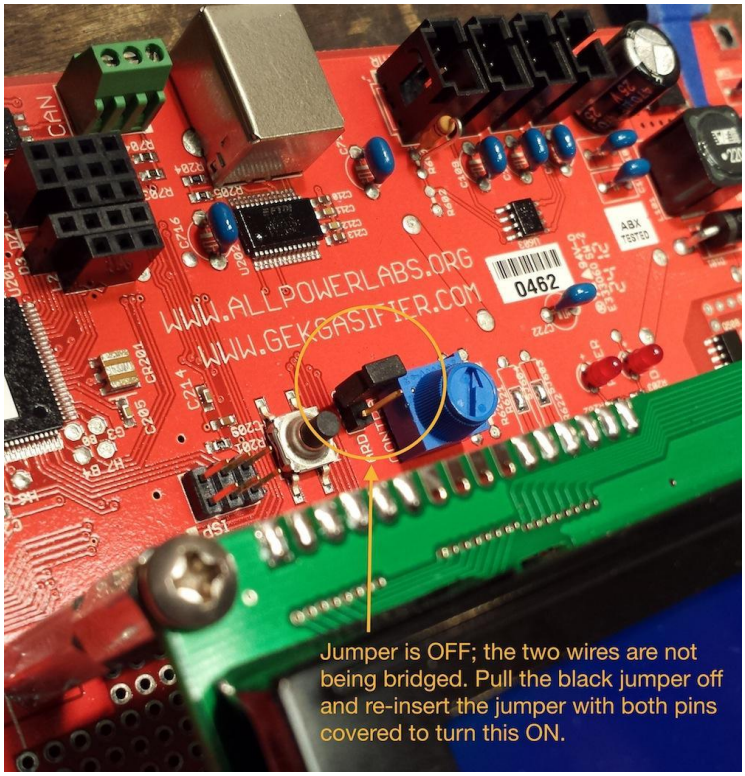
- **Computer** (Windows)
- **USB cable** (Power Pallet exterior USB connector has B-type socket; A-B USB cable provided in user kit)
- **FTDI USB Serial Driver** (Driver software is required to communicate with the PCU via USB link. Drivers are available at http://www.ftdichip.com/FTDrivers.htm)
- **Arduino Programming Software (for versions prior to 1.2)** (v0.20 - v0.23) (Arduino software is available from the Arduino website: http://www.arduino.cc/en/Main/software). Please familiarize yourself with the Arduino software before continuing: http://arduino.cc/en/Guide/HomePage
- **KS Library Package (for versions prior to 1.2)** (Download the libraries here: KSlibs - Arduino Support Libraries. (Please see the Arduino instructions for *Manual Installation* of the libraries: http://arduino.cc/en/Guide/Libraries).
- **KS Power Pallet Software Source Code for software versions prior to v1.2:**
    - (The latest stable version of the PCU software can be downloaded at https://github.com/allpowerlabs/KS_PowerPallet). Extract the files to your Arduino sketchbook folder.

- **KS Power Pallet Compiled Binary for software versions v1.2 and later:**
    - For a copy of this file please contact support@allpowerlabs.org.

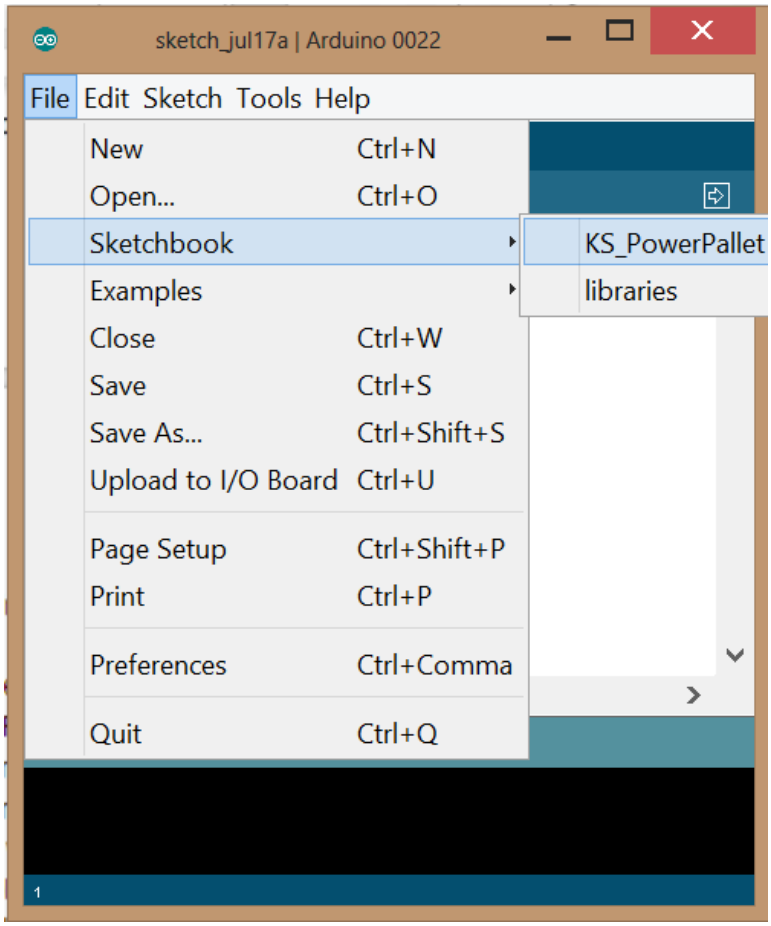
Uploading the Firmware

Warning: Ensure the Power Pallet is completely powered off before performing this operation and that the engine key is in the off position (all the way left).

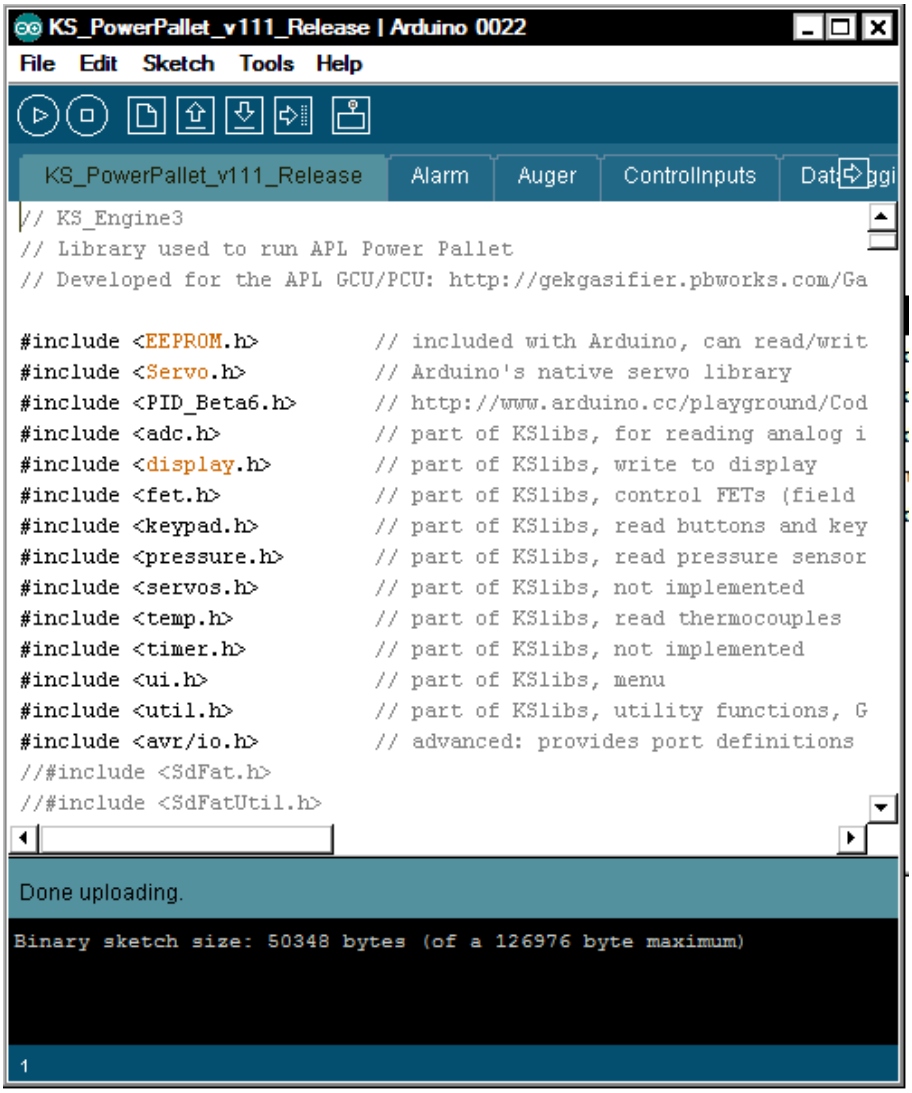
1. Connect the PCU reset jumper (ARD).



2. Connect computer to programming port on the front control door using USB cable (provided in the user kit).
3. Start the Arduino software and load “KS_PowerPallet.pde” (only for versions prior to 1.2).



4. Turn on the Power Pallet using the power switch on the front control door.
5. Select the correct board type using the menu, “Tools> Board> Arduino Mega (ATmega1280)”
6. Select the correct serial port using the menu, “Tools> Serial Port”. The exact name of the port will vary, but it will not appear in this menu before the Power Pallet is powered on. You can also check the COM port assignment in the “Device Manager” on your computer.
7. Press the “Upload” button. Wait for the upload to complete, which should take approximately 1 minute. If you encounter an error at this point, please stop and consult the “Troubleshooting” section below before continuing.
8. Power off the Power Pallet and disconnect the programming jumper.

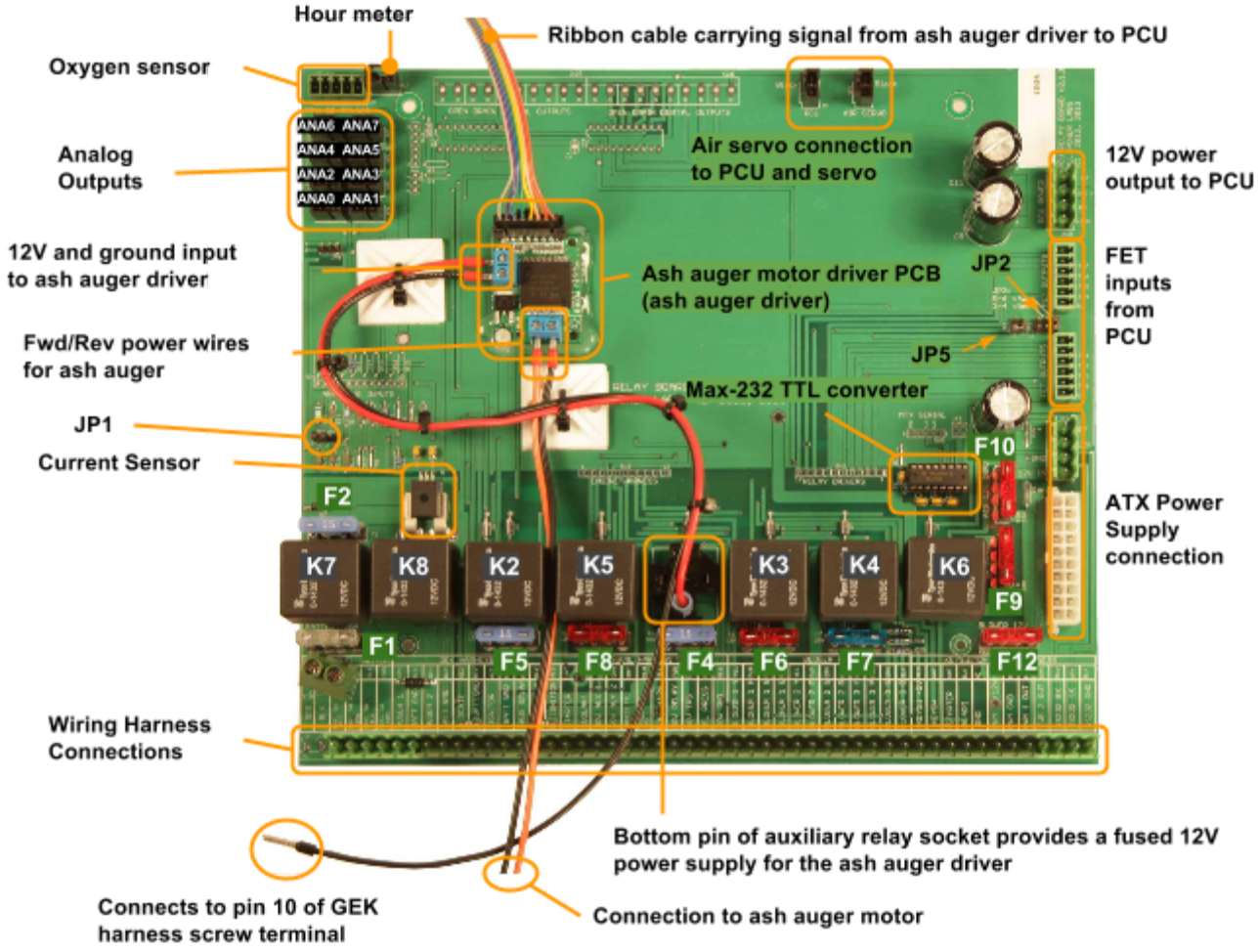


The Arduino interface showing that PCU program KS_PowerPallet is uploaded.

Relay Board

Introduction

The Relay Board receives the power and data through the wiring harnesses, and manages input/output signals to the various subsystems and the PCU. Please refer to this diagram for the descriptive sections on the following pages.



Relays			
K1	*Relay power pin provides +12V to ash auger PCB*	K5	Flare ignitor
K2	Grate shaker	K6	*Not Used*
K3	Engine ignition and governor	K7	Fuel auger forward
K4	Engine starter	K8	Fuel auger reverse

Fuses					
F1	25A	Main battery power	F7	15A	Engine starter
F2	15A	Fuel auger forward/reverse	F8	10A	Flare ignitor
F4	15A	Ash auger (v1.08 or newer) – previously Aux	F9	10A	Oxygen sensor reset
F5	15A	Grate shaker	F10	10A	ATX power input
F6	10A	Engine ignition, governor, hour meter	F12	10A	Blowers

Power Terminals

12V DC and ground connections power the entire automation system.

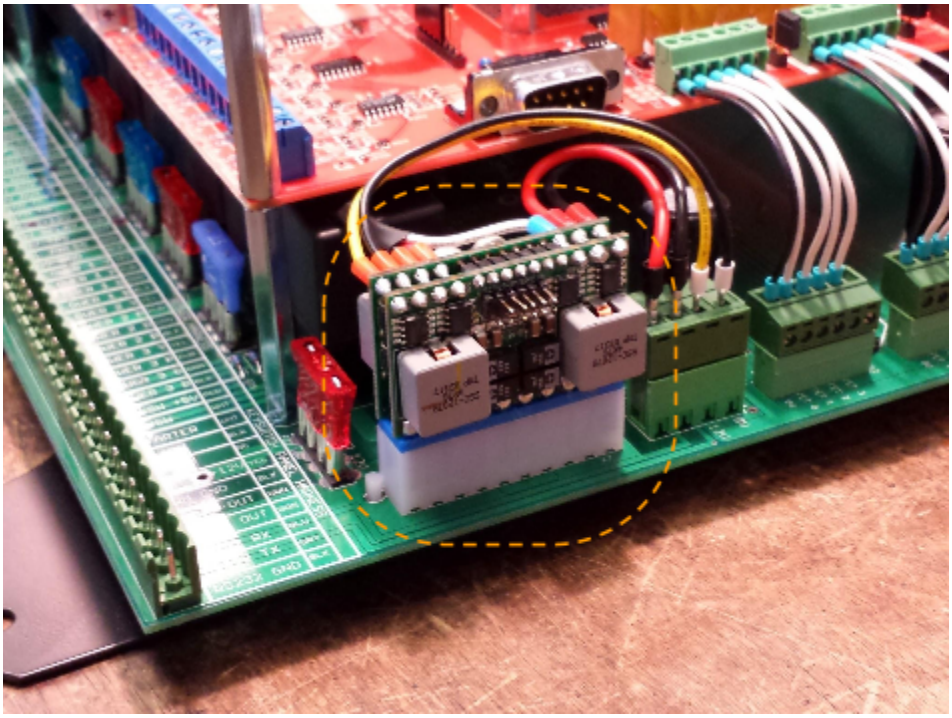
Current sensor

The relay board includes a Hall-Effect sensor that measures the current flowing through the fuel auger circuit. This enables “smart reversing” of the fuel auger. If there is feedstock jamming the fuel auger, the amount of current that the auger pulls will spike, as it attempts to push through the jam, which the current sensor will pick up and pass the information to the PCU through an analog input (ANA4). Once the current passes a certain threshold, the PCU will know the fuel auger is jammed and reverse its direction. This will generally dislodge the jammed feedstock. If it does not, the PCU will command the fuel auger to cycle backward and forward repeatedly, which will almost always clear the jammed feedstock.

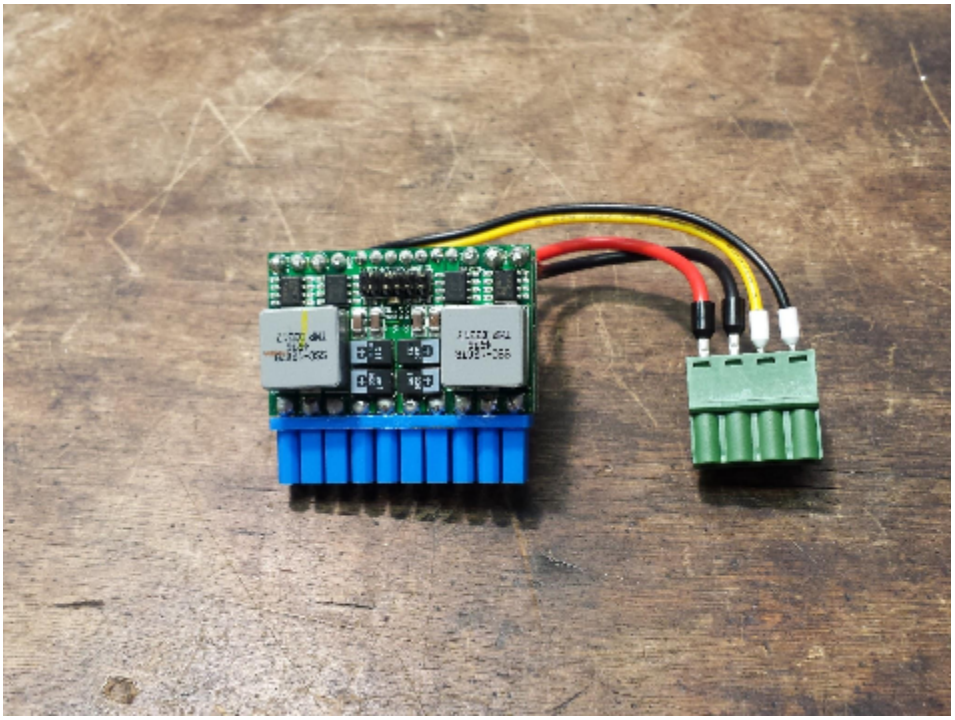
Ash Auger Motor Driver PCB

The *ash auger motor driver PCB* (often called the *ash auger driver* for short), is a standalone PCB that is a functional H-bridge which drives the motor allowing the ash auger to run both forward and backward. The ash auger driver also has an integrated current sensor, the output of which feeds back to the PCU through ANA7, enabling the PCU to automate smart reversing of the ash auger, just like the fuel auger. The ash auger driver uses a fused 12V DC supply from the Auxiliary relay socket to power the motor, while taking the ground from the GEK harness at the bottom of the relay board. 5V DC logic level power is supplied to the motor driver board through ANA7, and the output commands from the PCU originate from the Port D and Port L I/O expansion headers on the PCU. A Pulse Width Modulation (PWM) input to the motor driver PCB from the PCU allows variable control of motor power. Orange and black forward and reverse wires run directly from the motor driver PCB to the ash auger motor.

ATX Power Supply Module



Most automated subsystems draw current from the on-board 12V DC battery supply, including some motors with large current requirements, which significantly reduce the instantaneous voltage in the system as they come on. To prevent voltage drops from resetting the PCU, or power spikes from damaging the PCU, the ATX power supply unit provides clean 12V DC power to the PCU. The ATX module is a standalone power supply mounted on the relay board with connections in its 20-pin socket and in/out power connections to the relay board in a separate 4-pin screw terminal.



The ATX power supply unit

Relay Board Configuration Jumpers

JP1: Oil Pressure Sensor/Sender
3 pin jumper

- Jump Pins 1 (leftmost) & 2 (middle) = PP20 configuration (indicated on board)
- Jump Pins 2 (middle) & 3 (rightmost) = PP10 configuration (discontinued)

JP2: Alarm Enable & Relay Selection (O2 reset or Auxiliary)
6 pin jumper

Pin #	Position	Notes
1-2	Leftmost pins	Pins must be jumped to enable the audible alarm. All PP20 systems will have these pins jumped.
3-4	Middle pins	These two pins must be jumped to operate the ash auger **ONLY** on **v1.08** systems with **NO MOTOR DRIVER PCB** installed. [If there is a ribbon cable connected to ANA7 and L0-L2/D0-D2 I/O expansion ports on the PCU, then a motor driver board is installed.] The majority of Relay Boards will not have these pins jumped. These pins will **NOT** be jumped on v1.06 systems.
5-6	Rightmost pins	These two may be jumped to enable the Lambda meter to automatically reset under error conditions. These pins should be jumped on: a) v1.06 Power Pallets, b) v1.08 Power Pallets **WITH** an ash auger motor driver PCB installed. They are **NOT JUMPED** on v1.08 systems without an ash auger driver PCB.

JP5: Currently Unused
4 pin jumper
Jump bottom 2 pins

Max-232 TTL converter

This integrated circuit provides an electrical buffer for serial communication with the engine governor.

Analog Connections from Relay Board to PCU

These connectors output various analog signals from the Relay Board to the PCU.

Oxygen Sensor Controller

This connector powers the oxygen sensor (lambda) meter, which enables proper functioning of the air/fuel mixing system, and relays the analog signal (0.25 - 5V analog, 51 - 1023 digital value) to the PCU. Under reset or error conditions the oxygen sensor gauge on the front panel outputs 0V.

Hour Meter

This connector provides power to the hour meter when the engine ignition relay is activated.

Air Servo

These are pass-through connections from the PCU to the air servo. Control signal is passed through from the PCU while power for the servo is provided by the ATX power supply.

FET Inputs from PCU to relay board

The FET inputs are used to control relays based on signals from the PCU. A relay is activated when the PCU connects the pin on its respective FET connector to ground. For example, connecting the “FET 1” pin on to ground (0V) will turn on relay 1, activating the grate shaker motor.

FETs *From PCU to Relay Board*			
FET 0	Fuel auger forward	**FET 4**	Flare ignitor
FET 1	Grate shaker	**FET 5**	Ash auger
FET 2	Engine ignition	**FET 6**	Alarm
FET 3	Engine starter	**FET 7**	Fuel auger reverse

Wiring Harnesses

The GEK, Engine, Blower, and Key Switch harnesses connect to the bottom of the relay board with plug-in screw terminals, through which power and signals are routed to and from the the relay board, PCU, and automated subsystems on the Power Pallet. Please contact support@allpowerlabs.org if you require detailed diagrams and pinouts, as the harnesses are consistently upgraded.

Main Power Switch

A 30A breaker is used as the main power switch for the Power Pallet’s automation system, providing protection from over-current events. When it is flipped up into the “on” position, it powers the automation assembly with 12V DC from the main battery.

Engine start key switch

The engine start switch is a three position, spring return (OFF - ON - MOMENTARY) key switch, much like that in a typical car. The leftmost position is off. The switch is an input to the PCU and does not directly control any circuit: its functions are completely software defined. The “on” positions powers on the engine and governor, while the third “momentary” position starts the engine.

PWM blower controls

The gas and air blowers are controlled by two pulse width modulation (PWM) circuits located on the back of the podium door and operated by dials on the front of the door. The PWMs send out a series of pulses, the duty cycle of which changes with the turning of the dial switches, providing signal on a continuum for smooth increase and decrease of blower speed.

USB Port

The Universal Serial Bus (USB) port, labeled "PCU", is a serial connection that allows a computer to communicate with the PCU. The operator may use it to upload control code and to download and log run data. The outside port is a B-type female socket, so the operator will need the A-B male-male USB cable from the User Kit in order to connect his or her computer to the Power Pallet. It is important to keep the waterproof cap on the USB port when the connection is not in use in order to protect the connector against the elements and mechanical disturbance.

Troubleshooting

Troubleshooting FETs

To test operation of a FET output, use a voltmeter on the low-resistance or diode-check setting. The meter should read a low resistance to ground when the FET is switched, on and infinite resistance when it is switched off.

Firmware Upload Troubleshooting

Symptom	Possible Cause	Solution
PCU serial port does not appear in menu / “Serial port not found” error when uploading	FTDI USB serial driver not installed	Install USB serial driver on computer
Unable to find COM port	USB cable not connected	Verify USB connection at top of PCU, back of podium front door, and front of podium front door.
Unable to find COM port	No power to PCU	Turn on Power Pallet using power switch on podium front door
Error "avrdude: stk500_getsync(): not in sync: resp=0x00" when uploading	Programming jumper not set	Ensure programming jumper (ARD) is set.

Relay Board Troubleshooting

Symptom	Possible Cause	Solution
Subsystem not functioning	1) Fuse may have blown	Check fuse and replace if needed (wire connection in center of fuse is broken and plastic housing is discolored/darkened).
	2) Wires disconnected	Check all connections in screw terminals on harnesses (at bottom of relay board) and on FET screw terminals at relay board. Check that all connectors on the other ends of the harnesses are fully plugged into their mates. Use visual inspection and continuity test with volt-meter
	3) Circuit boards, harnesses, or subsystems incorrectly wired	Check all connections in terminals inside the enclosure and at subsystems against Wiring Harness Documents (found in appendices to Technician's Handbook). Use visual inspection and continuity test with volt-meter.
	4) Faulty connection to PCU	Check that PCU FET outputs and analog inputs have a solid electrical connection.
	5) Faulty relay	Replace relay with spare
	6) Faulty subsystem component	Check voltage at subsystem when PCU commands it on. Replace if necessary.
	7) Faulty component on PCU	Check voltages on PCU. Replace PCU f necessary. (see section on FET output troubleshooting)
Fuse blows more than once.	Shorted wiring connection	Check for shorted connections on relay board or swapped wires in harnesses and subsystem (refer to Wiring Harness Documents found in appendices).

Troubleshooting the PCU

Symptom	Possible Cause	Solution
Unable to read LCD screen/ nothing on LCD screen	1) Contrast non-ideal for lighting conditions.	Adjust the blue contrast knob or cover the LCD screen to shade from direct sun.
	2) Display connection not secure.	Check and secure connections.
	3) Display malfunction.	Replace display.
	4) ATX power supply may be faulty	Check that the green ATX LED on the right side of the relay board comes on. If not, replace ATX.
White blocks across the screen	1) Contrast not ideal	Adjust contrast knob
	2) Firmware corrupt	Re-upload firmware
LCD screen stuck on splash screen	Program timing glitch due to key switch being on when automation is turned on	Turn key switch to the OFF position and power cycle system.
Incorrectly proportioned pressure values	1) Pressure lines incorrectly connected	Connect pressure lines to correct ports on PCU
	2) Sensor offset calibration incorrect	Remove lines, calibrate sensors (see page 6 of this chapter for details)
Incorrect temperature readings	1) Thermocouple extension disconnected or connected to incorrect socket	Verify thermocouple extension connections at PCU and at connection to thermocouple
	2) Thermocouple faulty	See section on operational troubleshooting
PCU resets when USB cable connected or disconnected	ARD jumper set	Disable ARD jumper