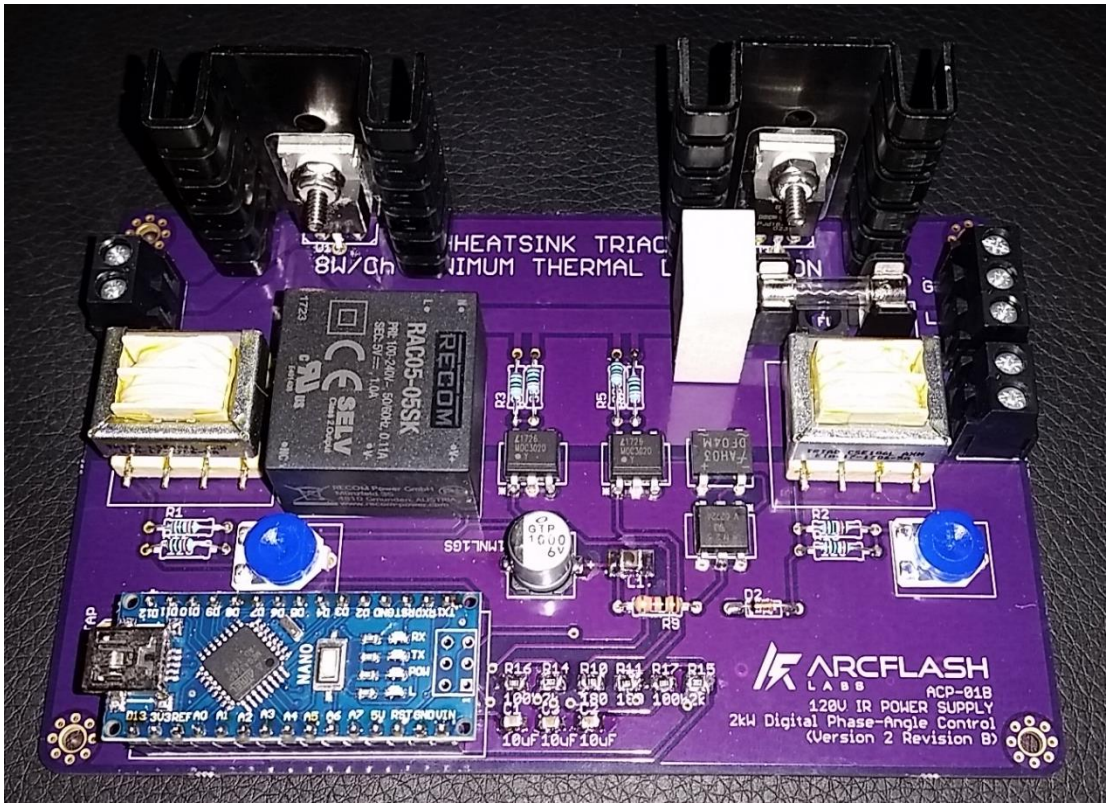
ACP-01B
2kW Digital Phase-Angle Controller

User Manual



Arcflash Labs, LLC
15032 Avenida Venusto
San Diego, CA 92128 - (424) 256-5087
www.arcflashlabs.com • admin@arcflashlabs.com

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1. Introduction

The Arcflash Labs ACP-01B is a high power, 120VAC-rated digital phase angle switching controller with dual 10A Triad Magnetics' Current Sense Transformers (CST's) which allow for dual independent RMS current detection through both output channels. The ACP-01B is controlled by an Atmel ATMega 328P (Arduino Nano) microcontroller which can be configured to accept commands via Serial, ICSP or I2C communication modes. The ACP-01B is designed to control up to one (1) 1kW Infrared emitter on each of the two separate channels. The unit is designed for forced-air active cooling, but heatsinks may be removed and triacs mounted directly to the case if passive cooling is desired.

- Up to 2kW output power (1kW per channel) at 120VAC
- Infrared controller compatible with single or dual emitters
    - Independent AC-RMS CST on each channel
    - True RMS power output for repeatable performance with different emitter types
- Replaceable 10A fuse
- Each unit pre-calibrated and tested to ensure repeatable performance
- Serial, ICSP or I2C compatible software communication modes
    - Outputs: Watts, Amps and Volts every second via serial
    - Inputs: Pre-load program, start command, stop command
- Continuous duty and high-frequency pulse operating modes

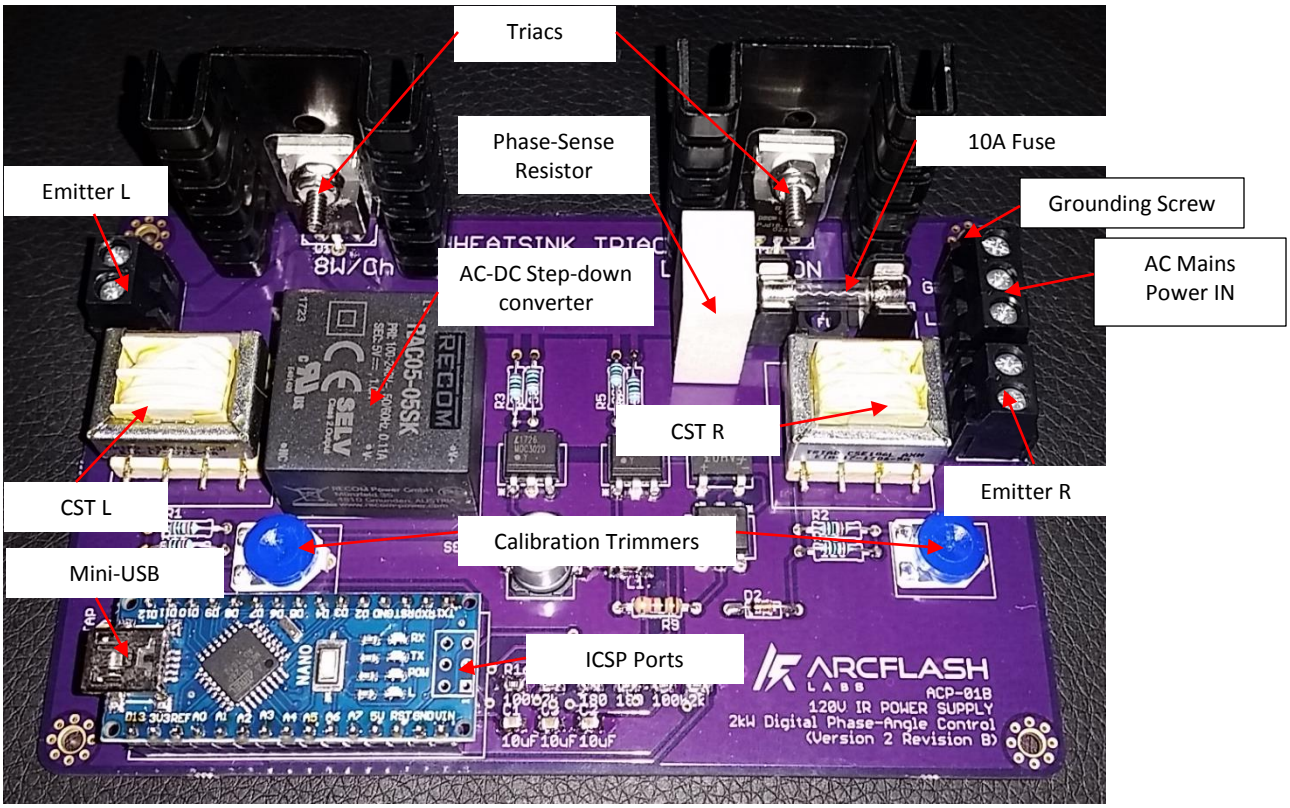
1.1 Terminology and Safety

The ACP-01B controls mains AC voltage. Touching certain components while the unit is connected to AC mains may be harmful or fatal. Certain software settings and/or trimmer adjustments could result in damage to the device and/or connected components, overheating, fire, or other property damage. Some components may become hot during operation and if touched could cause burns or other injuries. The following terminology is used throughout this manual to denote hazards and other important safety information:

An operation, procedure, or practice which if not correctly followed could result in personal injury or loss of life.

An operation, procedure, or practice which if not strictly observed, could result in damage to the device and/or voiding of the device's warranty.

2. Overview of components



- Always disconnect AC Mains Power and Use Caution Before Making Connections!
- Connect all grounding screws to case or enclosure before connecting AC live wire.
- The Triac heatsinks AND Phase-Sense Resistor may reach temperatures of >40C under load and can cause burns. The Phase-Sense Resistor is always powered, even when the emitters are off.

- Triac heatsinks must be actively cooled or triacs must be mounted to a suitably large metal surface for passive heatsinking.
- Do not adjust Calibration Trimmers. Adjustment of calibration trimmers will cause incorrect wattage output/readings and may cause CST secondaries to exceed design voltage and damage the CSTs or microntroller.

2.1 AC-DC Step Down Converter

The RECOM RAC05-05SK is an ultra-compact 120VAC to 5VDC Class-II step down switching converter operating at 130kHz with <1% ripple under load. It produces stable, regulated logic voltage suitable for direct line-in to the onboard microcontroller and up to 500mA of overhead to power auxiliary systems. The board is capable of supplying this power directly through the 5V+ and GND rails of the USB port and can power a Raspberry Pi simply by plugging in the USB. However, it is important to note that not all Raspberry Pi's are configured to accept line in

power via their USB ports. For this reason, an auxiliary 5VDC power tap is also available on the board located next to the USB connection.

2.2 Phase-Sense Resistor

The Phase-Sense Resistor is a 10kOhm 5W ceramic wire-wound power resistor which is used to regulate current to the 4N25 photodiode directly from the AC mains. This component eliminates the need for a costly 60Hz step-down transformer, but generates a significant amount of heat when the unit is plugged in. This component will draw power (approximately 3W) at all times, even when the emitters are off, and will remain hot even when the triacs are not operating.

2.3 Emitters

Connect emitters to screw terminals on left and right sides. Polarity of line and neutral wires is irrelevant so long as emitter cases are properly grounded.

3. Operation

1. With main power de-energized: connect Neutral, Ground, and Live wires to AC Mains Power IN screw terminal. Connect Ground and Neutral first before connecting Live.
2. Insert screws through grounding screw holes and ensure adequate connection to case or enclosure.
3. Connect emitters to L and R screw terminals.
4. Connect Raspberry Pi or other computer running serial control software to the USB or ICSP port.
5. Energize mains power.
6. Control device via serial commands listed below in (4) Software.

- Ensure USB cord and other wires remain clear of the Phase-Sense Resistor and other heated components.

4. Software

4.1 Serial/ICSP

The ACP-01B can accept a number of discrete commands via serial/ICSP. The ACP-01BB Serial buffer operates at 115200 baud and has a buffer length of approximately 30 characters. Instructions should be kept short and higher level processors should wait for confirmation or status updates before sending new commands. Below is a list of example input commands that can be sent to the ACP-01B via Serial or ICSP along with their functions:

PROG0:	Tells the microcontroller to store a string of instructions placed after the ":" character in the memory slot indicated after "PROG". It is recommended to ONLY transmit PROG commands when the lamps are off or in an idle setting, as reading long strings of serial text could disrupt the phase angle control and cause the lamps to flicker. Each step is stored in its own slot in memory. It is possible to change instructions in any slot without affecting other slots. Must be followed by a set of instructions less than 30 characters in length and a semicolon terminating character.
P0:	Same as "PROG0:". It is recommended to use "P0" vs "PROG0" due to its smaller size.
EXEC;	Tells the microcontroller to execute all commands currently stored in program memory in order, beginning with instructions set in PROG0 and continuing until PROG11 is reached. After PROG11 is reached, lamps will return to IDLE power.
IDLE;	Immediately turns both emitters to the idle power set via SETIDLE. Idle power is automatically set to 10.0% at device startup.
ES;	Emergency stop. Microcontroller will attempt to power down all emitters to 0% immediately upon receiving this command. This command also engages hard latch pulldown resistors on the triac gates. A hard reset must be performed after an emergency stop in order to turn the emitters back on.
SI:	Sets the idle power for both emitters. Must be followed by a number (in tenths of a watt) and a semicolon terminating character.
SI:250;	Sets the idle power to 25.0 watts for both emitters.
CL;	Clears all pre-programmed instructions in the buffer, resetting them to their default values with all slots as a default idle command.
CA;	Recalibrates the lamps to determine their resistance and maximum wattage. This command also clears the memory. This is automatically performed at startup and should never be necessary to call during normal operation. If this command is sent, nonstandard output data may be pushed to the serial stream. This command is intended only for debugging by the manufacturer.

The PROG command accepts gcode-like statements which control emitter power level, timing and mode. Unlike traditional gcode which is fed by a computer into a microcontroller continuously, this program relies on precise timing of the light source. Therefore, the code must be pre-loaded into the microcontroller before it executes. Examples of such commands are shown below along with a brief description of their functionality.

- Do not attempt to transmit long strings of continuous instructions to the microcontroller. Serial buffer size is limited to 30 characters. Attempting to ram through multiple instruction sets without waiting for confirmation could cause erratic behavior. It is recommended to wait at least 1s after transmitting a line of program instructions before transmitting the next line.

PROG0:L500,R500,T0,NORM;	A line of instructions which programs the microcontroller to turn L and R emitters on at 50.0 watts continuously and indefinitely until further instructions are sent. The microcontroller will not execute

	any programmed commands until the EXEC command is sent. "NORM" indicates normal operating mode.
`P0:L900,R800,T0,NORM;`	A line of instructions which programs the microcontroller to turn on Left Emitter at 90.0W and Right Emitter at 80.0W indefinitely.
`P0:L100,R100,T35,NORM;` `P1:L200,R200,T0,NORM;`	A line of instructions which programs the microcontroller to turn on both emitters at 10.0W for 3.5 seconds, then both emitters to switch to 20.0W indefinitely afterwards.

`P0:L200,R200,T35,NORM;`
`P1:L500,R500,T45,NORM;`
`P2:L100,R100,T0,NORM;`
	A line of instructions which programs the microcontroller to turn on both emitters at 20.0W for 3.5 seconds, then both emitters to switch to 50.0W for 4.5 seconds, then both emitters to switch to 10.0W indefinitely afterwards.

`P0:L500,R500,T50,HFP30;` `P1:L100,R100,T0,NORM;`	A line of instructions which programs the microcontroller to activate High Frequency Pulse on both emitters for 5 seconds with 3s pulse period. The emitters will oscillate between 50.0W and idle power, then both emitters will switch to 10.0W power indefinitely afterwards.
`P2:L100,R100,T0,NORM;`	A line of instructions which sets program slot 2 to turn on both emitters at 10.0W power indefinitely.
`P0:L50;`	Changes just the left emitter power to 5.0W in program slot 0.
`P1:HFP30;`	Changes just the operation mode in program slot 1 to HFP with 3.0s pulse period.
`P0:T100;`	Changes just the step time to 10.0s in program slot 0.

As soon as the ACP-01B emitters are switched on, it will begin outputting data at a rate of 1Hz in the form of comma-delineated strings:

`STATUS:L4518,R4516,T410,HFP10;`

L4518	R4516	T410	HFP10	;
Left Emitter wattage (tenths of a watts, i.e. 451.8W)	Right Emitter wattage (tenths of a watt, i.e. 451.6W)	Time since current operation started** (tenths of a second, i.e. 41.0s)	Indicates High Frequency Pulse operating mode @ 1Hz***	End of instruction block

*In future versions, the Emitter names (L and R) may be replaced by numbers (1-4) in future versions which feature higher power ratings and more emitter sockets.
**Times will show "0" if there is no time limit set for the current operation or if the emitters are activated in manual mode.
***High Frequency Pulse operating mode will attempt to flash the specified bulb at high frequency. The number after "HFP" indicates the pulse period in tenths of a second. Pulsed mode has a preset 50% duty cycle and oscillates between idle and the desired power setting. Values under 3 may not do anything useful and may be, in effect, the same thing as just changing the lamp's output power. "NORM" indicates normal mode (continuous).

- High Frequency Pulse may shorten the life span of the IR lamp

4.2 I2C

I2C commands are not supported in Version 2 Revision B but may be supported in later versions upon request.

4.3 Memory

The ACP-01B stores programmed commands for later execution in its dynamic RAM and will lose all stored instructions when power is turned off. This was done to improve the lifespan of the unit (as EEPROM has a limited number of read/write cycles), and due to the expectation that permanent storage would be the responsibility of higher-level microcontrollers (such as RPI) connected via USB.

The ACP-01B may store up to 12 instructions in the current revision. This is likely close to the hard limit for storage on the Atmel328P, even using EEPROM.

It is possible to circumvent this instruction set limit by passing single PROG instructions to the microcontroller followed by the EXEC command. However, this is not recommended as parsing PROG instructions is a slow process (comparatively speaking), and instructions passed in this manner could take up to a 0.5s to register an effect at the emitters. This delay is unpredictable and may result in unreliable pulse timing.

4.4 Calibration

The software performs an auto-calibration routine at startup. This involves turning on both lamps at full brightness for approximately 3 seconds. This is necessary to calibrate the current sensor transformers with the bulbs hot. Since hot bulbs have a different resistance than cold bulbs, it is necessary to take the resistance measurements when the bulbs are at their maximum brightness.

The software CST calibration can automatically correct for differences in filament resistance, inductance, line power frequency and line power voltage. When the device is instructed to deliver 50.0 watts to the emitters, it will compensate for differences in all of these factors (filament resistance, filament inductance, line power frequency and line power voltage) to deliver precisely 50.0 watts.

The software CANNOT automatically determine the emissivity or efficiency of the bulbs at converting electrical energy into light. This must be accomplished through the use of an external blackbody sensor.

Effective Radiated Power (ERP) correction factors are not implemented in this firmware version and likely will not ever be implemented on the firmware because they are computationally intensive. If ERP correction factors are desired, it is recommended to implement such corrections on higher level microcontrollers.

Under no circumstances should the user attempt to adjust the hardware calibration trimmers on the board. The hardware calibration trimmers are calibrated during testing using a reference standard and are not user-serviceable.

- Adjustment of calibration trimmers will cause incorrect wattage output/readings and may cause CST secondaries to exceed design voltage and damage the CSTs or microcontroller.

5. Hardware Specifications

Power Supply Input	120 VAC
Power Supply Output	120 VAC, 5 VDC
Current Rating	8A per emitter, 500mA on DC bus.
Dimensions	5” x 3.2” x 1.8”
Weight	5 Oz