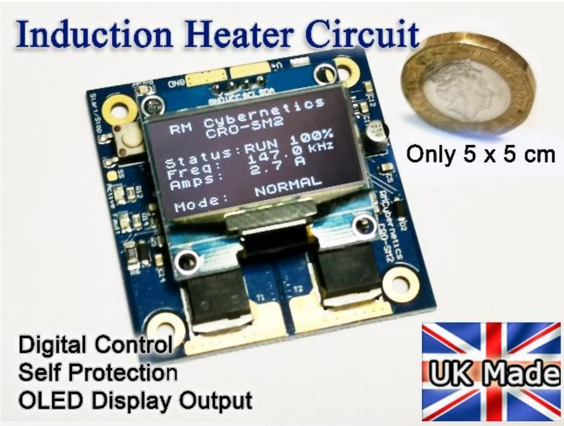
Mini Induction Heater Circuit

(ZVS Power Resonator)

CRO-SM2

Ultra Compact Self Resonating Power Oscillator for Induction Heating and Wireless Power



Features and Specifications

- Automatic Resonance, no tuning needed
- Ultra-compact size: L50 x W50 x H8*** mm
- Wide supply voltage range (12V – 26V)
- ZVS (Zero Voltage Switching)
- Current up to 20A continuous*, 70A peak
- I^2C output for OLED displays
- Digital protection from overload
- Built in output power control
- Flat base for mounting directly to metal enclosures**
- High quality double layer PTH, 2oz Copper PCB

** Max current varies with operating conditions.*
*** Electrical isolation required using thermal interface material*
**** Excluding Heatsink.*

Example Applications

- Induction Heating
- Wireless Power Transmission
- Solid State Tesla Coils
- DC-AC and DC-DC Power Inverters
- 3D Printers
- Annealing
- Metal Casting
- Heat Treatment & Hardening
- Resonant Energy Experiments
- And more…

Typical Usage

The most common use for the CRO-SM2 is as an induction heating circuit. When connected to an appropriate coil like our CT-400 coils, it can be used for induction heating with peak power levels up to 500W. This power level is adequate for heating small parts to red hot temperatures.

The small size and versatility of the CRO-SM2 makes it ideal for embedded applications where it is integrated into a system to provide the induction heating element.

The CRO-SM2 is an updated replacement for our popular product the CRO-SM1. We also offer customisation services where we can write custom firmware, or build custom electronic devices for you.

Optional Display

The PCB has an I^2C output for connection to common OLED display modules. When connected, the display will show the output status, resonant frequency and input current. Other information (input voltage, input power, coil voltage, and PCB temperature) can also be displayed in diagnostic mode. All these values are constantly monitored by the circuit for protection, if any parameter goes outside limits, or resonance fails, then the output driver is shut down, and an error code will be displayed. These errors are also displayed by a flashing LED so the display is not essential for operation. See the special modes section for more details on using a display.

Mode of operation

The CRO-SM2 is a type of collector resonance oscillator circuit which will automatically drive low impedance LC tank circuits at their resonant frequency. This is ideal for making a **DIY Induction Heater** or Wireless Power circuits. It is designed to drive a parallel LC circuit (a coil and capacitor connected in parallel) like our CT-400 coils. It can be connected in numerous configurations, but generally is used to drive a coil with power fed to it by an appropriately sized choke.

The system is activated by a push button built onto the PCB, or can be connected to an external switch or microcontroller. One press will activate/deactivate the resonant power output while a long press can be used to cycle through the power modulation modes. Onboard LEDs or the optional display will indicate the output mode and status.

The circuit will **automatically drive at resonance** even if the resonant frequency changes such as when a metal object is placed inside an induction heater.

It is important to read ALL these instructions carefully to ensure that the circuit will operate properly. If there is anything you are not sure about, please contact us for support.

ELECTRICAL CHARACTERISTICS

NB: Figures may vary under different loading conditions and environments.

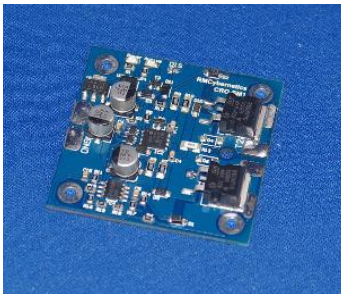
Symbol	Parameter	Min	Typical	Max
V_{in}	Input Supply Voltage	12V [1]	15 V	26 V
V_{power}	Load Supply Voltage	0 V	15 V	30 V
I_{sup}	Supply Current (no load)	20 mA	30mA	50 mA
I_{out}	Continuous Output Current	0 A	-	20 A [3]
I_{pulse}	Pulse Current [2]	-	-	70 A
V_{logic}	Logic (High) Voltage	3.3 V	5 V	5 V
T_{limit}	Thermal Protection Threshold	-	90 C	100 C
$V_{CoilLimit}$	Coil Voltage Protection Threshold	-	85 V	-
$V_{InLimit}$	Input Voltage Protection Threshold	10 V	-	28 V
I_{limit}	Current Protection Threshold	8 A	-	20 A

Table 1: Electrical Characteristics

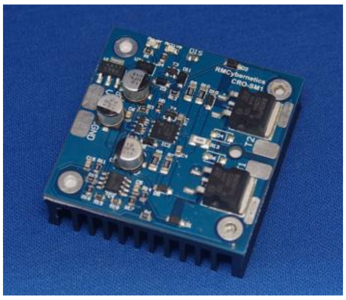
[1] 12V is absolute minimum. 14 to 24V recommended. [2] Pulse current is transistors max rated DC current at 25°C.
[3] Max current depends on cooling and operating frequency. At >100kHz we suggest no higher than 10A

Cooling Options

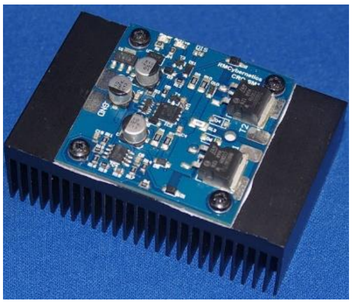
To switch more power, the circuit must be kept cool. Below you can see three typical passive configurations. The heatsink required will vary depending on various factors such as ambient air temperature and the operating frequency. You can also used forced air cooling (a fan) mounted to cool the component side to improve the power handling capability.



PCB Only



Small Heatsink



Large Heatsink

Figure 0: Various Heatsinks

Connections

The CRO-SM2 circuit can be powered from a 12V to 26V supply, while the load device its self can be powered form a separate lower voltage supply if desired. Typically, the circuit and load will both be connected to the same supply for simplicity.

Connections are made by soldering directly to the solder pads provided on the PCB. Note that this will require a good soldering iron or to pre-heat the PCB as the thick copper surfaces will quickly dissipate applied heat.

Power to the load must be delivered via a suitable power inductor or choke. A typical choke could be 85uH and rated for enough current to suit your application. For induction heating at typical power levels we suggest using the 100uH 15A choke available on our website.

The load supply (V_{power}) should be connected to a suitable DC power supply which is rated for typically 10A or more.

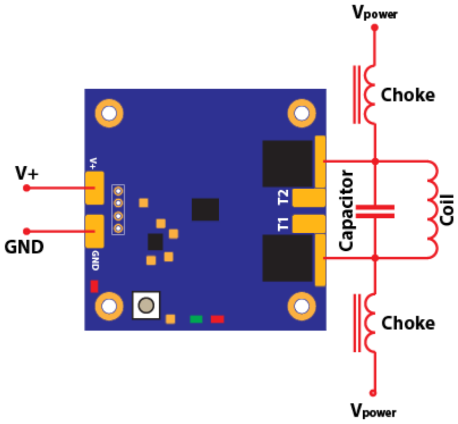


Figure 1: Connection diagram for standard coils

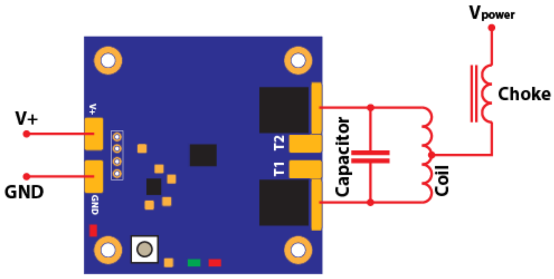


Figure 1b: Connection diagram for centre tapped coils

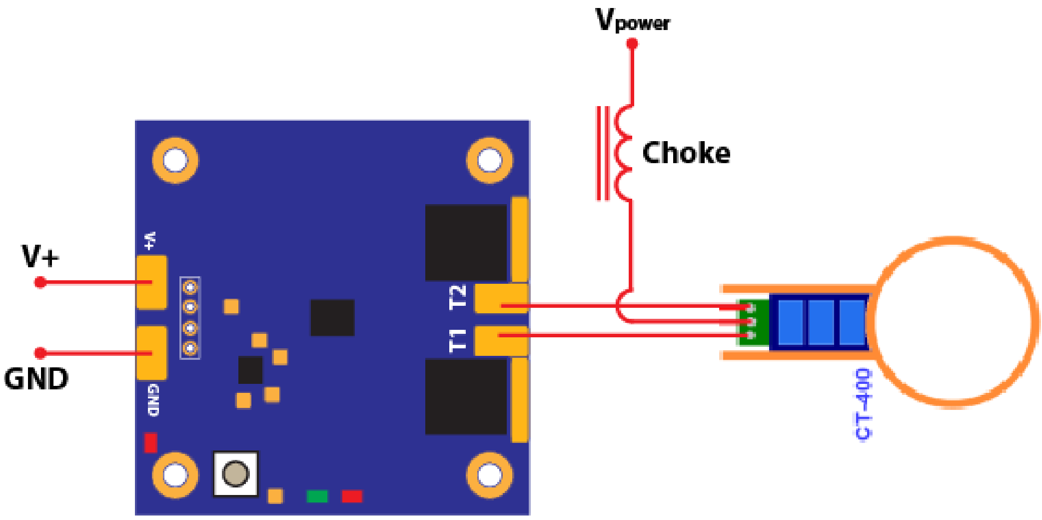


Figure 1c: Connection diagram for our CT-400 coils

Connection	Description
V+	Circuit positive supply input 12V to 26V DC
GND	Circuit ground or negative supply input
V_{power}	Load positive supply input to choke (can be connected to V+ for single supply use)
T1, T2	Connection for load
Choke	Use suitable inductor with current rated for your application recommended >50uH
Capacitor	Tank capacitor(s) to form part of the resonant circuit. Must be polypropylene or equivalent
Coil	Load coil such as transformer primary or induction coil

Table 2: Connections

The output connections are labelled T1 and T2. These are connections for the ends of a load coil and capacitor. Note that the output terminals do not themselves supply any voltage. The voltage for the load must be provided via a choke (inductor) to T1/T2 or the centre connection of a centre tapped coil.

The coil to be resonated should also have suitable capacitors in parallel with it. It is the inductance of your coil and the total capacitance that will determine the operating frequency. When connecting to a resonant load such as an induction heater or DRSSTC, the coil and capacitors should be connected to each other as close as is practically possible and should also connect very close to the circuit. Long wires can cause problems with oscillations starting up or poorly shaped waveforms.

The image below shows a typical setup where the CRO-SM2 is used to make an induction heater. The parts used can be found in the related products section below.

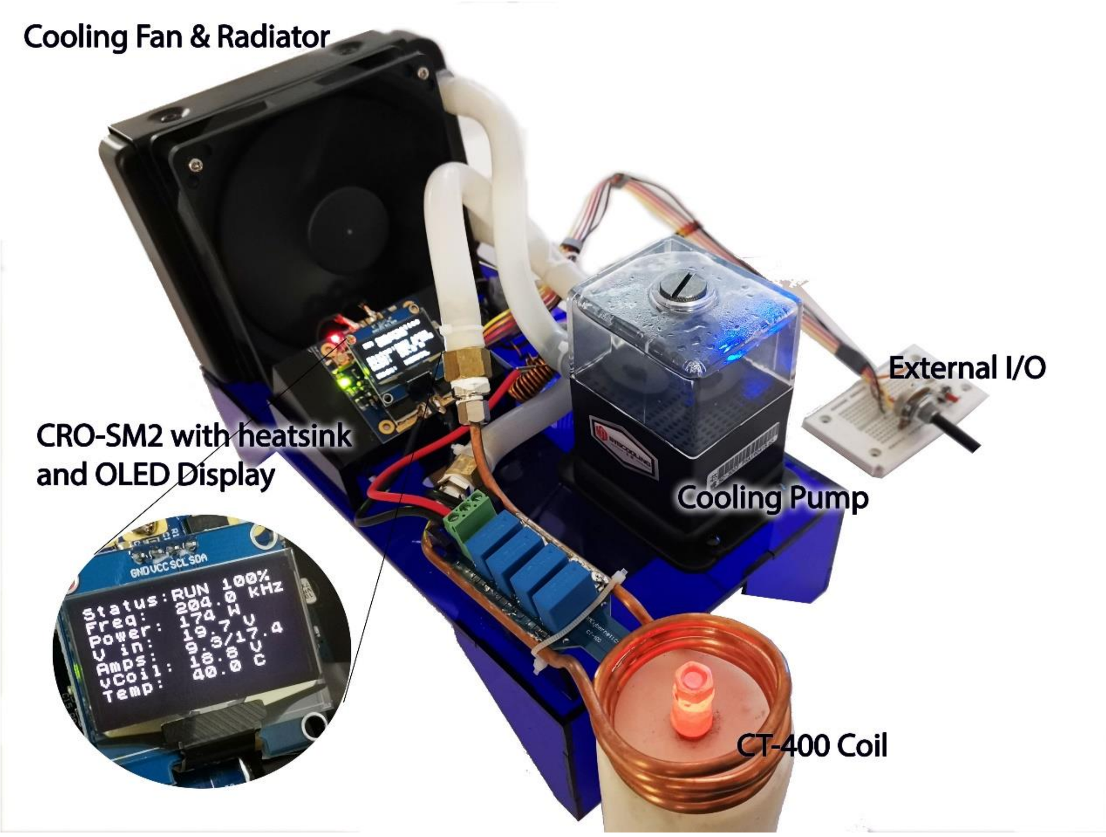


Figure 2: Example Water Cooled Induction Heater Setup

In the example above, the induction coil is water cooled. This is essential due to the very high currents oscillating between the coil and capacitors.

When there is no workpiece (metal) placed inside an active coil, the coil current will be higher and cause more waste heating. The CRO-SM2 has an optional mode where it can limit power until a workpiece is added. See *Special Modes* below for more details.

Output Load Considerations

The current oscillating between the coil and capacitor bank will be much higher than the input current to the circuit (V+ or V_{power}) and therefore the coil must be made of very thick wire, litz wire, or copper pipe and may need to be water cooled.

It is important to use good quality polypropylene (or equivalent) capacitors that are capable of withstanding large currents and show good temperature stability. Using low quality capacitors will result in no resonance, poor efficiency, or possible circuit damage.

Induction Coil Shapes and Sizes
The size of the coil used will determine its inductance. Larger coils have more inductance for the same number of turns. The example in the photo above is about 4cm in diameter and is

about the smallest size that will work with only 4 turns. This had an inductance value of around 700nH. If a smaller diameter is required, then a larger number of turns will be needed to keep the inductance high enough. If the inductance is too low, then the circuit will fail to oscillate and the output will be disabled.

Protection Circuits & LED indicators

Three LEDs are used to indicate the operational status of the CRO-SM2. A red Power LED indicates the board has power applied to the inputs, a green LED comes on when the output transistors are active, and another red LED is used to indicate errors and modes of operation.

The CRO-SM2 has a range of built in protection systems to prevent accidental damage and to provide reliable operation. Fault conditions are indicated by the number flashes of the red Fault LED followed by a pause. In any fault condition, the output is disabled. To restart the circuit, press the Start/Stop button to clear the fault, the press again to enable the output.

Flashes	Fault	Cause
1	Input Voltage too High	A voltage of around 28V or more has been applied to the input. This can be caused by input power spikes. Sustained over voltage will cause the circuit to shut down. Note that continuous voltages over 26V may cause permanent damage to the circuit.
2	Input Voltage Too Low	The input voltage has dropped below the minimum required for normal operation. This can happen if your PSU is unable to deliver enough current when switching on or adding a metal workpiece to an active coil.
3	Coil Voltage Too High	Coil voltage can rise in resonant conditions or from power spikes. If it rises above the safe threshold, this fault code will activate. This is more likely to occur with high inductance, low capacitance loads, or when no workpiece is inside an induction coil.
4	PCB High Temperature	Onboard thermistor is detecting a high temperature. Improved cooling is needed to operate if this is occurring.
5	Overload (High Current)	Too much output current. This can be due to a short circuit, or the metal workpiece in a coil being too large. The max current that triggers this fault will change with the detected PCB temperature. Higher temperatures will lower the max current rating. The optional OLED display will indicate the max allowed during operation.
6	Resonance Failure	Coil failed to resonate. This can be due to a faulty / incompatible coil, too large of a work piece, or other issue. This can occasionally occur anyway, but if it happens often, then check for problems with the setup.

Table 3: LED flashes and fault codes

Proper system design is essential for long term reliable operation. It is not recommended to operate the circuit continuously when protection modes are activating as more heating in the circuit may occur. The protection circuits should only be considered as backup as failure to operate the circuit within specifications could cause the transistors to fail.

Notes on Protection

The PCB must be mounted on a heatsink for the temperature sensor to work correctly. It is also important to consider that some components (such as the output transistors) may heat up very quickly in high load conditions and could therefore fail before the temperature sensor has warmed up and detected any problem.

The protection circuits have limited response time and may not be able to protect from very large fast transients or changes. When using an OLED display, there is an added latency between detecting error states and shutting down.

Power Modulation

You can adjust the heating power of a resonating coil by simply adjusting the supply voltage. Alternately, you can use the CRO-SM2's built in modulation function to select a power level of either 25%, 50%, 75%, or 100%. To select a power level, hold the on/off button until you see the green LED flash. The number of flashes indicates the power level selected. Keep holding the button down to cycle through the available power levels. Power levels can be adjusted when the output is either on or off.

Flashes	Power Level
1	25%
2	50%
3	75%
4	100%

Table 4: LED flashes and power levels

The power modulation works by simply powering the coil on and off roughly every second or so. For example, at 25%, the coil will be powered for 250ms, and then off for 750ms. This cycle is repeated to give an average heating power of 25%.

Power modulation can cause current spikes and higher chances of resonance failure. It is not recommended to use this feature under high load conditions or when operating near the circuit's max ratings.

The power level selected is stored in memory and will be retained even after the circuit powers off.

Special Modes & External Interfacing

There are several small solder pads on the PCB which can be used to alter the way the CRO-SM2 operates. The pads are un-marked and quite small so will require identifying using the image below, and connections made carefully.

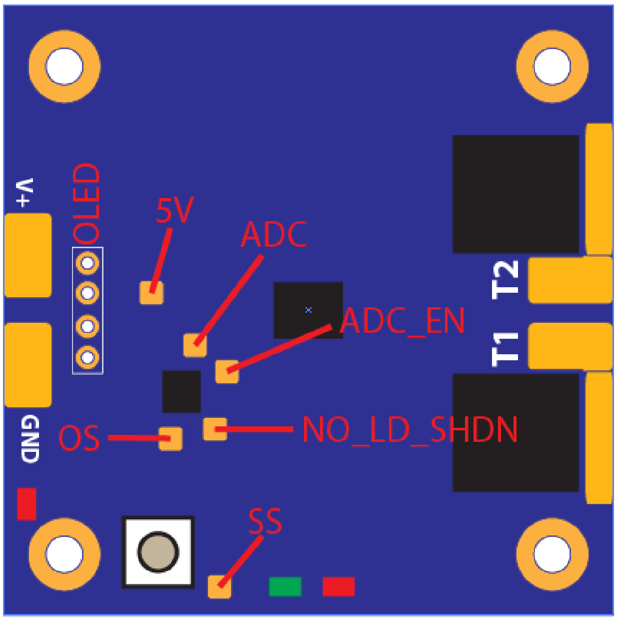


Figure 3: Special Connections

Pad ID	Function	I/O	Description
SS	Start / Stop	IN/OUT	Connected to the push button. Pull low then high to toggle power output state. Hold low then release to adjust modulation setting. **AUTO MODE** If held low during power up, the output will automatically enable after approximately 2 seconds and stay on until powered down or an error condition occurs. An error in this mode will only briefly disable the power output. After about one second, the output will restart. If the fault is not rectified and the device continues to retry, damage to the circuit may eventually occur.
OS	Output State	OUT	Pad is set high when the circuit power output is active. Useful for when interfacing with a microcontroller for automation. Note that when power is being modulated, OS will remain high even during the low part of the modulation cycle.
ADC	Analogue input for sensor	IN	**ADC WAIT MODE** When a voltage applied here exceeds approximately 1V, the power output is disabled until this voltage falls back below 1V. Useful for automatic temperature regulation using an external probe.
ADC_EN	Analogue input enable	IN	Pull low to enable the ADC pin, otherwise it is ignored.
NO_LD_SHDN	No Load Shutdown	IN	**SET CURRENT MODE** With the power output running, briefly pulling this pin low will save the current power state as the minimum acceptable load. The value is stored in non-volatile memory and will function even after the circuit has been powered off and on again. If the measured current falls approximately 0.5A below this value, the power output will be disabled until the current is high enough again. Roughly every second, the coil will be pulsed to measure the current. To reset this value to zero, this input should be pulled low when the output state has been manually disabled. NB: This mode will not work while the device is in other special modes such as power modulating or using the ADC
5V	5V Output	-	Connection to the onboard 5V, 100mA regulator. Useful for powering an external microcontroller or sensors.

Table: 5 – Optional I/O interfaces

Using an OLED Display

Most common I²C OLED modules with a 128x64 pixel resolution can be used with the CRO-SM2. The pinout (bottom to top in figure 3) is GND, VCC, SCL, SDA. Compatible displays with a matching pinout are available on our website.

Note that all four pins for the display connect to the onboard microcontroller I/O and are limited to 20mA max,

The CRO-SM2 will automatically detect when a display is detected and change its operation accordingly. When a screen is used, there will be some additional latency in operating the controls and general responsiveness. Start-up time will increase from 2 seconds to about 4 seconds with a display attached.

By default, the display will show the output state, selected power level, resonant frequency, any special modes and error codes. Additional information can be displayed by starting the device in ***debugging mode***. To enter debugging mode, the GND connection of the screen must have an additional connection made between the circuit GND and the OLED GND before powering on the device. Debugging mode adds further latency to the operation of the device.

All variables shown are approximate and uncalibrated. Two different circuits may show slightly different values for the same parameters.

A display can be soldered directly to the PCB or a socket can be fitted to allow easy removal. If the CRO-SM2 is to be mounted to a heatsink, it is important to make sure that when fitting a screen, no pins or solder bumps are protruding through to the underside of the PCB. The underside of the PCB must be totally flat for proper heatsink mounting.

Important Usage Notes

- When experimenting with new loads, check the transistors are not overheating.
- High frequency operation causes more heating in the circuit and care should be taken not to overheat it.
- Use a current limited power supply to protect from accidental short circuit, overload or failed oscillation.
- Always use a fuse when used with PSUs rated above 10A. A 10A quick blow fuse is typical.
- At high power levels take care to only power the load for short periods and leave time for the CRO-SM2 to cool otherwise the transistors could fail. The hotter the device is running, the less power it can handle safely.
- Heat is transferred to the heatsink through thermal vias on the PCB which have high thermal resistance vs directly mounted transistors. Therefore, large increases in power level may cause the transistor temperature to rise faster than heat can be removed or detected by the onboard sensor.
- The PSU must be able to deliver enough current to suit your LC load. If it is not sufficient, this could prevent proper operation and damage the circuit. Adding a large electrolytic capacitor between V+ and GND can help to stabilise the supply from any voltage dips caused by start-up currents.
- Keep the wires between the circuit and load as short as possible (<10cm) when used in induction heater circuits such as our CT-400
- The heat generated in the switching transistors will vary with your loading conditions and the operating frequency. Higher frequencies will produce more heat.
- Adding a cooling fan over the component side of the PCB is an effective way to cool the device.
- The transistor/heatsink, copper surface, and LC load may rise to a higher voltage than the input supply when in use. Do not touch the PCB, heatsinks, or your load coil when powered.
- The output coil should typically be a small number of turns (<1000) for resonance to work.
- To drive more current into coils with more turns, you may need to use an impedance matching transformer.
- It is highly recommended to use a bench top PSU or fit the optional OLED display when using the circuit with unfamiliar loads. This will allow you to see if the voltage

drops, or the current rises too high while you are familiarising yourself with the system.

- When mounting on a heatsink, thermal interface material must be used to isolate the PCB from the metal surface. Do not use only thermal pastes as the circuit could short out on the metal heatsink.

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Customisation available for this product.

We can write custom firmware for this product and help integrate it into your project. Call or email to discuss your requirements.

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Related Products

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OLED Display	OLED1W3
PWM Circuit	PWM-OCX
Polypropylene Capacitor	CAPPOLYP400V330NF
Choke 15A, 100uH	CHK-15A
Heatsinks	See Website
Thermal Interface Material	BOND-PLY-100

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