Micro Induction Heater Driver
CRO-SM3
Ultra Compact Self Resonating Power Oscillator for Advanced Induction Heating

** Depends on operating conditions.*
*** Electrical isolation required using thermal interface material*
**** Normal range <250kHz. Higher range may require customisation.*

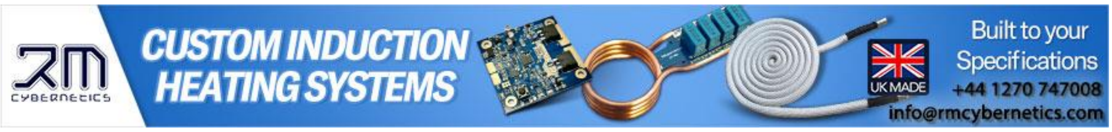
Features and Specifications
- High efficiency power resonator up to 500W*
- Adjustable output power
- Ultra-compact size: L50 x W50 x H6.8mm
- Modular design for easy product integration
- Wide supply voltage range (12V – 26V)
- Digital protection & monitoring
- Auto-resonance with wide frequency support up to 1MHz***
- Highly customisable and extendable
- Current up to 20A continuous*, 70A peak
- Optional Digital interfaces (I^2C, RS-232, ADC, I/O)
- Mixed PWM / Resonance mode options
- Flat base for mounting directly to enclosures & heatsinks**
- Ultra-high density, copper filled PCB for high performance

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

Typical Usage
Induction heating of small parts where space for components is limited. Capable of high frequencies and high power in an incredibly small package, the CRO-SM3 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-SM3 makes it ideal for embedded applications where it is integrated into a system to provide the induction heating element.

The CRO-SM3 is a high-performance induction heating controller suited to embedded applications and research. With a tiny 50x50mm footprint and modular addons, this powerful little module is perfect for developing a wide range of induction heating projects. We also offer customisation services where we can write custom firmware, design coils, integrate with products, or build fully custom electronic devices for you. Just get in touch to discuss your project.



Available Versions

Two versions are available to purchase. The ST version is the standard version with a range of features available for most applications and simple integration options. The PRO version contains a host of advance features and interconnectivity options outlined below.

	CRO-SM3-ST	CRO-SM3-PRO
Push Button On/Off operation	✓	✓
Selectable power level (25%, 50%, 75%, 100%)	✓	✓
Fault detection & protection	✓	✓
Digital I/O (5V) for on/off/error	✓	✓
Addon display support	✓	✓

RS-232 Serial Interface	✗	✓
Adjustable PWM power control (20-100%)	✗	✓
Timed mode	✗	✓
Workpiece detection mode	✗	✓
Temperature regulation mode	✗	✓
Selectable constant current or PWM mode	✗	✓
Adjustable PWM Frequency	✗	✓

Table 2: Feature Comparison of ST vs PRO model

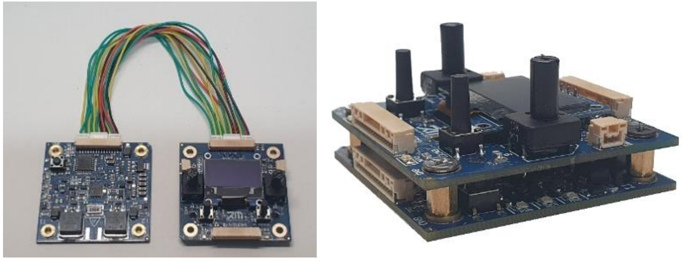
Modular Design

The CRO-SM3 micro induction heater driver is designed for simple integration in embedded applications requiring an induction heating component. With its compact size of just 50mm, and simple M3 mounting points, it is easily integrated into other systems. The 15-way connector provides multiple interfacing options for use with either our own addon modules, or to integrate with your own systems such as PLCs, microcontrollers, or Arduinos. Addon modules are stackable and connectable in virtually unlimited ways allowing the user to create unique solutions to their induction heating projects.

Figure 0: Example Module Stack

Expansion Board & UI (EXP-THERM1)

The EXP-THERM1 expansion board allows for easy access to a wide range of integrated features through the simple GUI on a small OLED display. This module is powered via the 15-way connector and can be mounted in top of other modules in a stack, or mounted separately as a remote control.

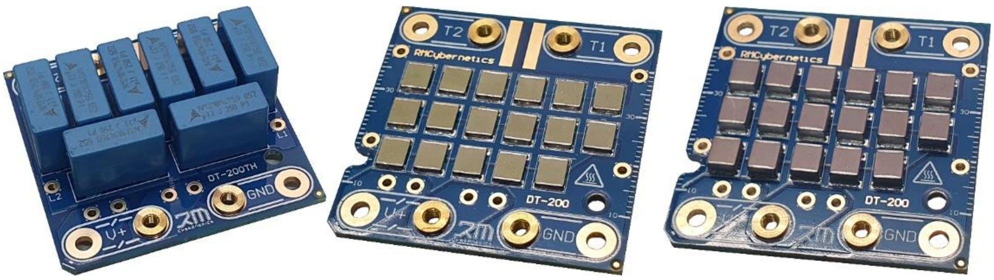


Also included is a type-k thermocouple amplifier for easy setup of temperature measurement and regulation up to 1000°C

See the EXP-THERM1 product page for full details

High Density Tank Capacitor Arrays (DT-200)

Tank capacitor choice is an important part in induction heating systems. A selection of MMC capacitor modules are available which can be stacked with other modules allowing for a highly efficient and compact system. A choice of capacitor types are available to suit a wide range of frequencies and power levels.



Modes of Operation

The CRO-SM3 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). 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. Choke-free operation is also possible by using a centre tapped coil.

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.

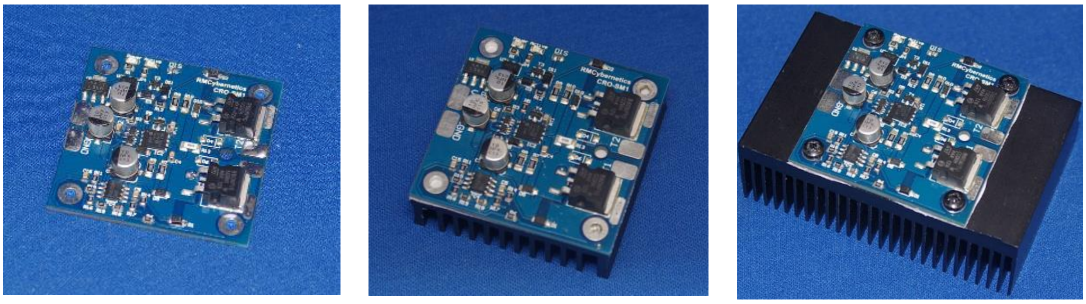
Symbol	Parameter	Min	Typical	Max
V_{in}	Input Supply Voltage	12V [1]	15 V	26 V
V_{power}	Load Supply Voltage	5 V	15 V	30 V
I_{sup}	Supply Current (no load)	20 mA	30mA	70 mA
I_{out}	Continuous Output Current	0 A	-	20 A [3]
I_{pulse}	Pulse Current [2]	-	-	70 A
V_{logic}	Logic (High) Voltage	3.3 V	5 V	5.1 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	18A	20A	22 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.

Cooling Options

The CRO-SM3 is built on a high-density PCB with copper filled vias to maximise passive heat dissipation. For very high currents and / or frequencies additional cooling may be required. 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 use forced air cooling (a fan) mounted to cool the component side to improve the power handling capability. If purchased with a heatsink option, it will be supplied with a piece self-adhesive thermal pad. Peel off the protective layer and use this to fix the PCB to the heatsink. No screws are needed. If mounting to a heatsink, take care to ensure that connection screws do not pass through and short out on the heatsink.



PCB Only **Small Heatsink** **Large Heatsink**

Figure 1: Various Heatsinks (NB: Photos are of previous model CRO-SM2)

Connections

The main connections for power and coil are made using the M3 threaded inserts in the corners of the board. Additional connections are available via the 15-way connector at the edge of the PCB. The onboard microcontroller is running at 5V so all external logic interfaces must be able to work at 5V.

The 15-way female socket on the CRO-SM3 is a JST “SM15B-GHS-TB”. The male plug housing to fit this is JST part number “GHR-15V-S” which uses crimp terminals “SSHL-002T-P0.2”

The CRO-SM3 circuit can be powered from a 12V to 26V supply, while the load device its self can be powered form a separate supply of a different voltage if desired. Typically, the circuit and load will both be connected to the same supply for simplicity.

PLEASE READ THE IMPORTANT USAGE NOTES ON PAGE 8 BEFORE USE

Power to the load is typically delivered via a suitable power inductor or choke. A typical choke could be 100uH 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 choke selected can form a significant part of the total size of your system. If you have tight space requirements, choose a choke with a current rating as close as possible to your expected peak current to keep the size down. Using a choke with a high current rating will also work fine with smaller currents, but is just physically larger.

The load supply (V_{power}) should be connected to a suitable DC power supply which is rated for typically 10A or more (this can be the same connection as V+). If you are experimenting, we recommend using a linear PSU with current limiting. Some SMPS may cause and error due to high peak start-up current. This can usually be circumvented by the use of an additional choke connected to the positive output of the PSU.

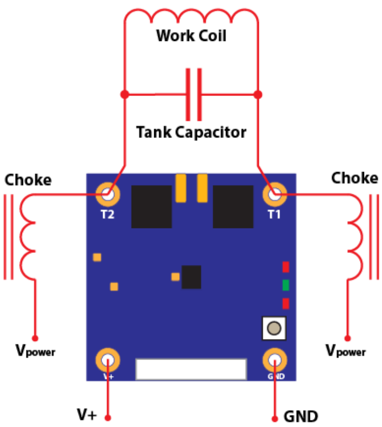


Figure 2: Connection diagram for standard coils

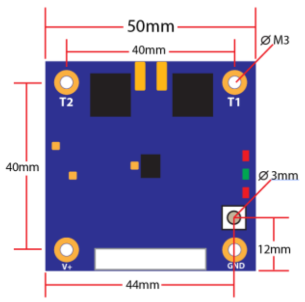


Figure 2c: Product Dimensions

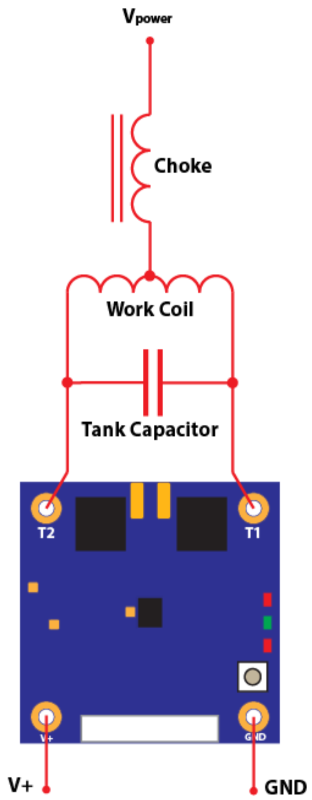


Figure 2b: Connection diagram for centre tapped coils

Connection	Description
V+	Circuit positive supply input 12V to 26V DC
GND	Circuit ground or negative supply input
V_{power}	Load positive supply (5V – 30V) input to choke (connect to V+ for single supply use)
T1, T2	Connection for load coil
Choke	Use suitable inductor with current rated for your application recommended >50uH
Tank Capacitor	Tank capacitor(s) to form part of the resonant circuit.
Work Coil	Load coil such as induction coil or transformer primary

Table 4: 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.

A tank capacitor is essential for proper resonance. These can be fitted externally, or as part of the modular stack using our DT-200 tank capacitor modules. It is the inductance of your coil and the total capacitance that will determine the operating frequency.

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. See our guidance notes for tips on practical implementations.

Optional I/O connections

The 15-way JST GH connector allows for simple interfacing with other devices and sensors

Pin	Function
1	***GND*** Common connection to ground / 0V
2	***5V*** Connects to internal 5V rail via 10R resistor
3	***AUX*** ***(PRO only)*** Programmable I/O can be set to use as a PWM output, or Thermistor input
4	***POT B*** ***(PRO only)*** ADC input for potentiometer on external control module
5	***POT A*** ***(PRO only)*** ADC input for potentiometer on external control module
6	***THERMOCOUPLE*** ***(PRO only)*** ADC input from thermocouple amplifier on external control module
7	***I^2C SCL*** Connection for external interfacing. Default setting is for use with standard 128 x 64 OLED display.
8	***I^2C SDA*** Connection for external interfacing. Default setting is for use with standard 128 x 64 OLED display.
9	***LED-RUN*** Signal for RUN LED on external control module
10	***LED-MSG*** Signal for MSG LED on external control module
11	***BUTTON-OPTION*** ***(PRO only)*** Input for OPTION button. Active Low with internal pullup enabled
12	***BUTTON-ENTER*** Input for ENTER button. Active Low with internal pullup enabled
13	***RS-232 Tx*** ***(PRO only)*** Serial interface for remote control. Connect this to Rx on your controlling device
14	***RS-232 Rx*** ***(PRO only)*** Serial interface for remote control. Connect this to Tx on your controlling device
15	***Factory Use Only***

Table 5: Pinout for optional 15-way connector

On startup the CRO-SM3 will perform a Power On Self Test. When connecting external modules like our EXP-THERM1, the board will flash LEDs to indicate it successfully detected it. The LEDs also indicate which version of the module you have (ST or PRO)

POST LED indication

	ST	**PRO**
MSG LED (red)	Flashes	ON if EXP detected
RES LED (green)	On if EXP detected	Flashes

Table 3: Power On Self-Test LED Status

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.

The size of the coil used will determine its inductance. Larger coils have more inductance for the same number of turns. If the inductance is too low, then the circuit may fail to oscillate and the output will be disabled.

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. We have a range of high-performance capacitors available on our website.

The combinations of coil, capacitor, and workpiece will have an effect on the operating frequency and the power drawn from your PSU. All these variables interact so proper consideration is needed if you are looking to maximise heating efficiency or work at a specific frequency.

Built-in Protection & LED indicators

Three LEDs are used to indicate the operational status of the CRO-SM3. 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. You can also see additional fault information with the expansion board or compatible OLED display.

The CRO-SM3 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 out of range	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. -OR- 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.
2	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.
5	Resonance Frequency Problem	Resonance out of range or not resonating. This can be due to a faulty / incompatible coil or capacitor, too large of a work piece, or operating out of the rated frequency range. This can occasionally occur anyway, but if it happens often, then check for problems with the setup.

6	Resonance Duty Problem	This occurs if the switching transistors are not sharing the load evenly. This can be due to a faulty / incompatible coil or capacitor, or operating out of the rated frequency range.

Table 6: 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.

Power Modulation

You can adjust the heating power of a resonating coil by simply adjusting the supply voltage. Alternately, you can use the CRO-SM3'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 MSG LED flash together. The number of flashes indicates the power level selected. Keep holding the button down to cycle through the available power levels.

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

Table 7: LED flashes and power levels

The power modulation works by interrupting the resonator at 1Hz with the user defined duty.

Power modulation can cause high current and voltage spikes with 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. Modulation can also affect the reliability features such as frequency measurement.

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

Important Usage Notes

When using this circuit for the first time we suggest following some basic guidance to ensure you will become familiar with its operation and to get the most use out of it.

Essential Considerations

Power Supply
At start-up there can be a brief high peak current before resonance starts. It is important that your PSU can deliver this current without dropping voltage otherwise it could fail to operate correctly or even damage the power MOSFETS. Your PSU must be rated for at least 10A for most induction heating applications. It can also help to add a large capacitor at your PSU output.

A linear PSU is usually most reliable, as an SMPS may shut down due to the high peak current on start-up. If using an SMPS we suggest adding an additional series choke at the positive output terminal of the PSU.

Output Connections

All wiring after the connection points of T1 and T2 forms part of the resonant circuit. Long trailing wires to your coil can have a significant effect on operation and should be avoided. Long wires may cause start-up failure or false resonance conditions which can both lead to damaged MOSFETs.
By connecting a tank capacitor directly to T1/T2 terminals, this will include your connecting wires as part of the resonant tank with your work coil. This may allow proper resonance with longer wiring, but it will lead to increased losses in those wires (unless using suitable litz wire). It will also mean that if you move/bend those wires, the output power and frequency may change due to changes in the inductance.

Work Coil Design

The work coil and tank capacitor will affect all aspects of operation including heating power, current draw and resonant frequency. A lager coil (more turns, or wider diameter) will lead to a lower resonant frequency and usually lower power levels. You should design your work coil to suit the PSU, workpiece and tank capacitor.
A smaller tank capacitor will lead to higher resonant frequencies, but added ESR (resistance) of using fewer parallel capacitors may lead to lower useful power levels due to component heating.

Workpiece

The size and material of your workpiece will have a very significant effect on the power consumption. Magnetic materials like iron will have a very strong reaction and will heat well, whereas non-ferrous materials like titanium, will have only a minimal response.
When the workpiece is within the coil, it can cause a large increase in current from the PSU. Your PSU must be rated to handle this. If the workpiece is within the coil before the CRO-SM3 is started, the large peak current could damage a MOSFET if power levels are high. We suggest starting resonance without the workpiece in the coil if possible.

Choke Selection

It is important that the choke is of sufficient size for your application and rated for at least the peak current that the system will see. If the inductor is saturated by excess current above its rating, this can lead to current surges that may damage MOSFETs or prevent resonance starting.

Other important considerations

- 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 linear 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-SM3 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 copper-filled 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 expansion board 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.
- I/O connections can be made using a 15-way, 1.25mm pitch, JST GH connector (MPN: GHR-15V-S)

Troubleshooting

If you are having trouble getting your system working, check the notes above and try the following suggestions.

Symptom	**Possible Causes**	**Solutions**
PSU cuts off when the coil is connected, and before pressing the Start/Stop button	Blown T1 / T2 MOSFET	Remove the output connections to the coil, and use a multimeter to test which MOSFET is blown. To do this set the meter to test for a short between the T1 or T2 terminal and GND. Replace any MOSFET that shows a short.
PSU cuts off when the Start/Stop button is pressed. Persistent Resonance Fail errors on start-up	PSU not suitably powerful for your setup. Bad output coil configuration or. Insufficient choke rating.	Use a PSU rated for more current, or one of a lower voltage so that less current will be drawn by the work coil. Shorten any connecting wires and make sure the tank capacitor is closer to the PCB Use a larger choke.
Low input Voltage	PSU not suitably powerful for your setup. Or resonance is failing.	As above

Table: 8 – Troubleshooting

Customisation is available for this product

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

Tel: 01270 747008 – Email: info@rmcybernetics.com

Related Products

Product	MPN
Induction Heater Coil	CT-400
Water Cooling Kit	IHWK-4M
12V, 30A PSU	12V30ASMPS
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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