ZVS Power Resonator

CRO-SM1

Ultra Compact Self Resonating Power Oscillator

Features and Specifications

- Automatic Resonance, no tuning needed
- Wide supply voltage range (12V – 30V)
- ZVS (Zero Voltage Switching)
- Current up to 10A continuous*, 70A peak
- Over Voltage, Current, & Temperature Protection
- Optional modulation input
- Flat base for mounting directly to metal enclosures**
- High quality double layer PTH, 2oz Copper PCB
- Ultra-compact size: L50 x W50 x H8*** mm

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

The CRO-SM1 is a type of **collector resonance oscillator** circuit which will automatically drive low impedance reactive circuits at their resonant frequency. This is ideal for making a **DIY Induction Heater** or Solid State Tesla Coil. It is designed to drive a parallel LC circuit (a coil and capacitor connected in parallel). It can be connected in numerous configurations and is also able to work with loads that have a centre tapped coil.

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.

The circuit is designed to work with a wide range of parallel LC (inductor capacitor) circuits which have a relatively low inductance and a large capacitance. For example an induction heater with a few turns on the coil and a large capacitor bank. While this circuit has been designed to be as versatile as possible, there may be certain LC combinations that will not be driven to resonance by the circuit.

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.

Example Applications

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

ELECTRICAL CHARACTERISTICS

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

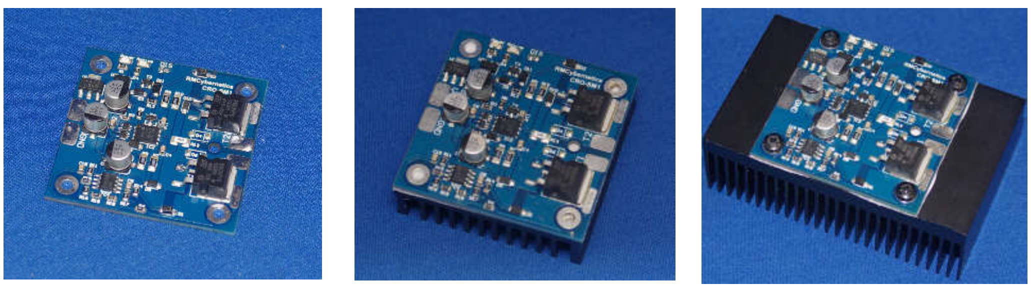
Symbol	Parameter	Min	Max
V_{in}	Input Supply Voltage	12V [1]	30 V
V_{power}	Load Supply Voltage	0 V	30 V
I_{sup}	Supply Current (no load)	20 mA	50 mA
I_{out}	Continuous Output Current	0 A	10 A [3]
I_{pulse}	Pulse Current [2]	-	70 A
T_{limit}	Thermal Protection Threshold	90 C	100 C
V_{limit}	Voltage Protection Threshold	80 V	85 V
I_{limit}	Current Protection Threshold	8 A	12 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

To switch more power, the circuit must be kept cool. Below you can see three typical configurations. The heatsink required will vary depending on various factors such as ambient air temperature and the operating frequency.



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

Figure 0: Various Heatsinks

Connections

The CRO-SM1 circuit can be powered from a 12V to 30V 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.

The output power is controlled using the connection pad marked DIS. This is used to activate and deactivate the circuit. DIS is held high internally when powered on which will prevent the power output from activating. To activate the output, DIS should be pulled low (connected to GND) via a switch or using another logic device such as a microcontroller or PWM circuit. The pad marked with the white border is the connection for logic, while the adjacent pad is GND.

If the circuit output is required to operate whenever there is power to the circuit, then DIS can be connected to ground by making a small solder bridge between the pads.

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. The inductance value of the choke is not critical but should be sufficiently high as to prevent high frequency currents working back into your PSU.

The load supply (Vpower) should be connected to a suitable DC power supply which is rated for at least 10A (preferably more). While batteries can be used it is generally not recommended as when the battery is low, there may be insufficient voltage at V+ for the protection circuits to work properly. This is also true if the PSU used is not able to deliver enough current as the voltage at V+ could drop below that required to operate properly.

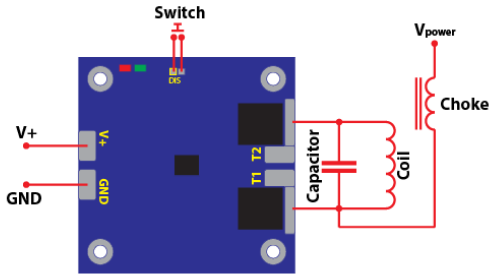


Figure 1: Connection diagram for standard coils

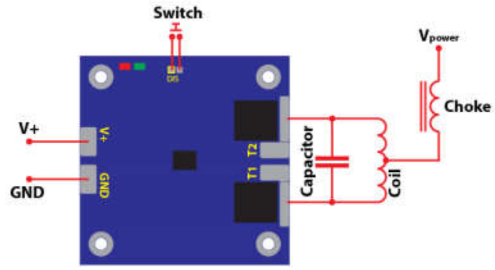


Figure 1b: Connection diagram for centre tapped coils

Connection	Description
V+	Circuit positive supply input 12V to 30V DC
GND	Circuit ground or negative supply input
Vpower	Load positive supply input to choke (can be connected to V+ for single supply use)
T1, T2	Connection for load
DIS / Switch	Digital on/off control
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

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 or the centre connection of a centre tapped coil. Figure 2 below shows a typical setup used for experimenting. Terminal blocks are added for ease of connecting different loads. The choke and startup capacitor are also soldered in place. Note that the cables for the load are kept short.

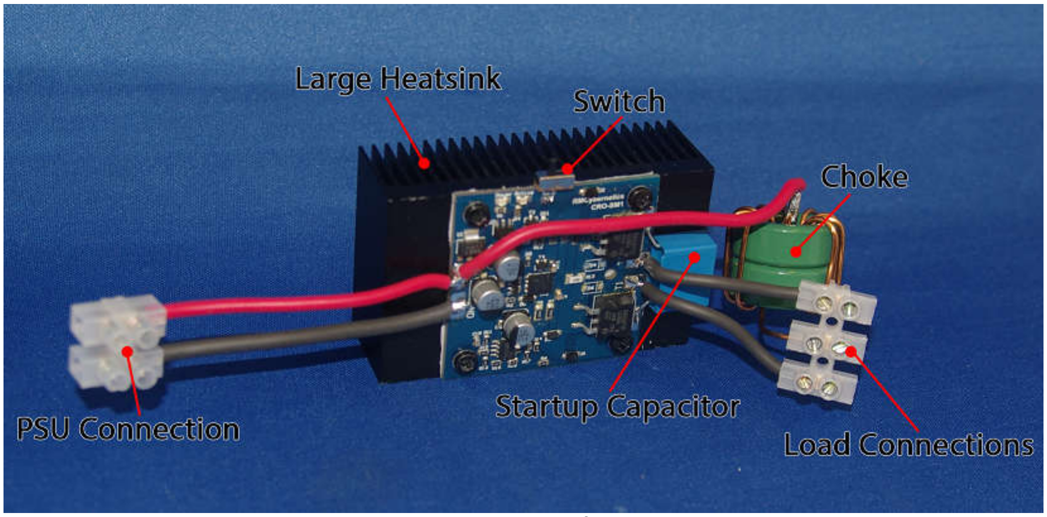


Figure 2: Typical connections for experimenting

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. If it is not practical to connect the load close to the circuit, a startup capacitor (such as a 330nF 400V polypropylene) should be fitted directly between the T1 and T2 connections on the PCB. When using low impedance loads such as induction heater coils, it is also recommended to solder a capacitor directly to the PCB at T1 and T2 as this will aid in starting proper oscillations.

The image below shows a typical setup where the CRO-SM1 is used to make an induction heater. The parts used can be found in the related products section below.

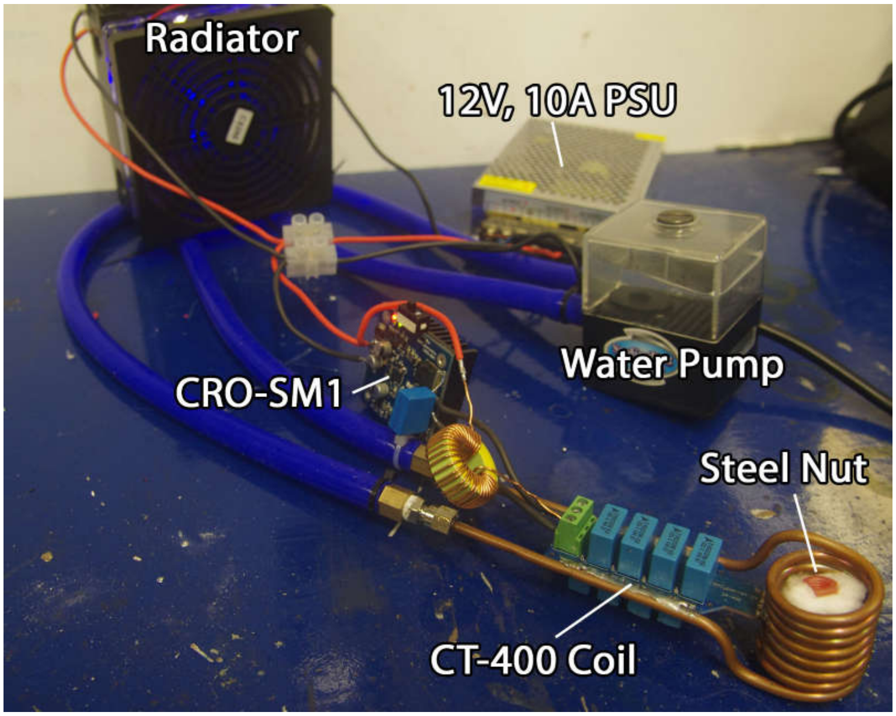


Figure 3: Example Water Cooled Induction Heater Setup

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. However the drive circuit only requires a small heatsink in this setup.

You can find more details and support for a DIY Induction Heater on our website.

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 Vpower) and therefore the coil must be made of very thick wire or copper pipe and may need to be water cooled if it is of low inductance.

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, 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 built in current limiter will activate.

Protection Circuits

The CRO-SM1 has a range of built in protection systems to prevent accidental damage and to provide reliable operation. However consideration needs to be given for all operating conditions including when in protection mode. 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.

When the protection circuits activate and deactivate, modulation of the output will occur briefly. This may be accompanied by a buzzing sound and dimming of the “Active” LED. When the circuit is modulated in this way, one of the output transistors may see significantly more current than the other and therefore get hotter. If a significant temperature difference between the two output transistors arises, then normal operation may become less stable. If the voltage input to V+ falls below 12V the effectiveness of the protection circuits will be compromised. Therefore it is essential that an adequate supply is used, or that V+ and Vpower are connected to independent PSUs.

Thermal Protection
A built in temperature sensor will disable the power output while the temperature exceeds the threshold. The power output will automatically re-activate once the device has cooled below the threshold temperature. If the load is continuously causing a thermal overload, the circuit should be given longer periods to cool as continuous operation at the thermal limit will significantly reduce the lifespan of the circuit. Note that 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.

Current Protection
The power output will be briefly disabled whenever the current exceeds the threshold. Within a fraction of a second the output will then re-activate and continue oscillating if operating within limits. It is common for the initial startup current to be quite high which will cause the current protection to activate briefly while resonance is established.

Voltage Protection
Resonating and pulsed coils can create voltage rises that are higher than the supply voltage. If the voltage at T1 exceeds the threshold, the output will momentarily be deactivated. Once the voltage falls, the output will be enabled again. The voltage protection circuit has a limited response time and may not be able to protect from very large fast transients.

Important Usage Notes

- **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-SM1 to cool otherwise the transistors could fail. The hotter the device is running, the less power it can handle safely.**
- 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.

- Adding a startup capacitor directly between T1 and T2 may be essential for some devices to resonate.
- 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.
- The transistor/heatsink, copper surface, and LC load may rise to a higher voltage than the input supply when in use. This will typically be 3.142 times the input voltage. Do not touch the PCB, heatsinks, or your load coil when powered.
- The output coil should typically be a small number of turns (<1000).
- 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 add a voltage/current meter 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 thermal pastes as the circuit could short out on the metal heatsink.

Power Modulation

It is possible to vary the average power output of the circuit by using a modulation signal provided by an external PWM circuit such our PWM-OCm or PWM-OCX v2. This is ideal for controlling the temperature of an induction heater. Modulation can only be done at a very low frequency such as <1 Hz. Frequencies higher than this will be filtered by the circuit and the output will simply remain high or low depending on the duty cycle of the modulation signal. Note that when modulating the output, each time the output activates, one transistor will see a large peak current before resonance is established. If the CRO-SM1 is running hot, large current pulses may damage the circuit.

Typical Application

The example in figure 4 shows the CRO-SM1 driving an induction heater coil CT-400, while being modulated with a PWM-OCm pulse width modulation circuit.

Connect both the CRO-SM1 and the PWM circuit to the same power supply so that they share a common ground connection then connect "DIS" on the CRO-SM1 to "L-" on the PWM (see figure 4 below). When the PWM output is on, it will connect DIS to ground and therefore enable the power output of the resonator. By setting the PWM to a very low frequency like 1Hz or lower, you can then adjust the duty setting to give a proportional adjustment in output power.

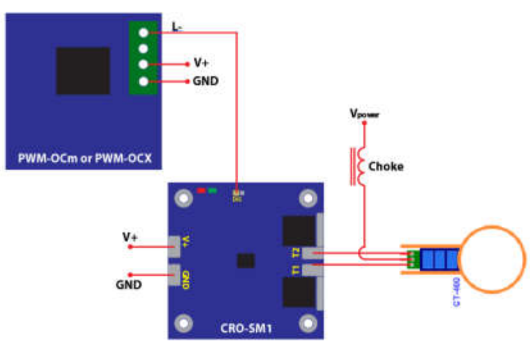


Figure 4: Connections to PWM and CT-400 for Modulated Induction Heating (not to scale)

Troubleshooting

If your setup fails to oscillate or has other problems, there are a number of possible causes that will be discussed below.

Insufficient PSU
If the power supply used cannot deliver enough current, then this will cause a large voltage drop on start-up which could prevent oscillation from starting. The only way to remedy this is to use a larger PSU rated for more current.

Wires Too Long
Long wires between the tank circuit (load) and the CRO-SM1 may prevent proper resonance or cause it to oscillate at an excessively high frequency. The wires from the circuit to load should be as short as practically possible and less than 10cm. If you need longer wires, then capacitors will need to be added directly between the T1 and T2 terminals.

Very Low Inductance or Resistance Coil
If the coil has too little inductance and/or resistance, this may prevent oscillation. You can remedy this by increasing the size of your coil. Even a tiny bit of additional inductance or resistance can make the difference between no oscillation and a working system. Just simply bending the connecting wires into a single loop between the coil and CRO-SM1 can sometimes add enough extra inductance to get the system running.

Too Much Inductance or Resistance
If the coil is made from too many turns, the inductance and resistance may be too large to support oscillation with this circuit.

Too Little Capacitance, or Poor Quality Capacitors
If there is not enough capacitance parallel with the coil, the oscillation frequency could be very high. This would cause significantly more heating in the transistors in the circuit.
Small, or cheap capacitors may also heat up quickly in use. By using more capacitors the frequency is reduced and the current flow is shared between them.

Extra capacitor needed between T1 & T2
In some systems it will be necessary to add a good quality capacitor between T1 and T2. Without this, some systems will just fail to resonate and cause the current limiter to repeatedly activate.

Blown MOSFET
If a MOSFET is blown from overheating, the DIS connection will no-longer be able to deactivate power to the load coil. The typical symptoms of this would be that your PSU voltage drops due to it being shorted through the coil via the bad transistor. You would need to replace these MOSFETs to get the circuit running again. To test for a blown MOSFET, remove all connecting wires, and use a multimeter to check for conductivity between T1 and GND or T2 and GND. Whichever one shows conduction needs to be replaced. The transistors used are STP60NF10, but you can use almost any MOSFET with similar ratings.

Related Products

Product	MPN
Induction Heater Coil	CT-400
Water Cooling Kit	IHWK-4M
12V, 30A PSU	12V30ASMPS
PWM Circuit	PWM-OCX
Polypropylene Capacitor	CAPPOLYP400V330NF
Choke	See Website
Heatsinks	See Website
Thermal Interface Material	TIM-100