The PVM500 operates on 115VAC only. (To use with 220VAC wall power, you will need a step-down transformer that converts 220VAC to 115VAC, and that can handle at least 300 watts of power. The TR220/110/300 is available on our website, or you may already have your own to use.)

**CAUTION:** plasma displays, and small objects can easily be damaged by the abrupt resonant power rise of this system. Always start with VA1 set at about 5 to 10% and increase slowly. Use your own judgement on damage point of your load.

### Controls and Inputs

- **VA1** Independent voltage level control
- **S1/RFreq** Main power switch and frequency control
- **S2** HI/LO voltage switch enables voltage doubler – *always start in LO position.*
- **Rdc** Duty-cycle/power control. See duty cycle explanation
- **NEON1** Power on indicator
- **AMP** Meter 0-3 amps for power input monitoring
- **FUSE** 4-amp slow-blow
- **J2** Remote control port with TTL input
- **J1** Frequency monitoring port (frequency and waveshape output)

The TTL input J2 to this product allows you to externally turn on and off any level of power you are working on at that time. Will The suggested highest rate of turning on and off should not be more than a second and the level must be such it is always a level that provides a positive on and off the mode, not in between.

This input can be used to synchronize with other circuits and gives the user good external control for coincidental operation with other functions.

A signal generator putting out a TTL output is recommended. However, any square wave output pulse generator will also work.

J1 allows you to monitor the frequency the unit is currently tuned to. It does not provide an actual facsimile wave shape that is on the load and its only figure of merit is the measurement of the frequency the unit is tuned to. Future units may have the input where the wave shape observed is a facsimile of what is on the load and frequency
Operation: before providing power to your load, first determine whether it is a straightforward resistive load (non-resonant), or the more complex reactive and resistive load (resonant). See the following explanations.

Non-Resonant

Instructions for Conventional Resistive (Non-Resonant) Loads [Uses SKU# COIL4000L]

Resistive loads are energized by direct contact with the energizing electrodes; an example would be a simple neon tube. In this mode of operating the unit automatically compensates for the negative resistance presented by the load. This is a common characteristic of any type of an energized gas. This feature also allows the load to be a short circuit without circuit damage.

There are many applications for a device with these properties; example powering a gas laser, a Jacob's ladder as a museum demonstration piece, driving a voltage multiplier, and many other direct contact applications.

1. Connect HV output lead to load. Note output is referenced to chassis ground that is earth ground via the green lead of the power cord.
2. Verify that the HI/LO switch is in the down position, VA1 is FCCW (fully counterclockwise), S1 is FCCW and Rdc is FCCW/OFF.
3. Plug into a 115VAC source and rotate VA1 a quarter turn. Apply power via rotating S1/RFreq control until it clicks on noting that the NEON1 indicator lamp comes on. Note: Units made before Jan 2013. NEON1 lamp only comes on when VA1 is set for above 60 vac
4. Slowly adjust S1/RFreq until the display or meter starts to activate. Note that the S1/RFreq control increases frequency in the CCW direction. Now slowly rotate VA1 CW noting desired effect. Note reading on the AMP meter for reference.
5. Now set Rdc to the desired current reading or display texture. Some loads may cause premature shutdown in using Rdc

CAUTION: Contact with the bare metal controls and other objects may cause annoying burns. This is especially noticeable when powering single ended plasma displays that are within several meters of the user. Insulated tubing may be placed on the control shafts to help avoid these annoying shocks and burns.
Resonant

Instructions for Complex Resonant Loads

A complex resonant load in the case of most plasma cells is where the plasma is applied by using capacitive plates on the outside of the containment structure, or one external cylindrical contact and one internal electrode. Example: many ozone cells are made this way.

An unfortunate disadvantage of using this type of cell structure is that in the complex notation the capacitance is very low, producing a very high reactance that becomes the dominant value, so now the impedance is mostly a function of this high capacitive reactance. This means a very high voltage must be applied to the device to get any power into the much lower resistance part of the load. This is not acceptable and causes many problems. A large high-voltage power transformer and strain on many circuit components as well as being very inefficient and costly are but a few. To get the most for your money, the capacitive reactance of the complex impedance must be tuned out. This is accomplished by operating at a resonant frequency, as determined by the capacitance of the cell and the internal structure of the transformer. Each transformer can achieve resonant frequency operation within a range of load capacitances, but transformers can be easily swapped out to provide a wide degree of flexibility that will cover almost all normal capacitive values.

A more comprehensive explanation is at the end of this document

1. Connect HV output lead to load. Note output is referenced to chassis ground that is earth ground via the green lead of the power cord.
2. Verify that the HI/LO switch is in the down position, VA1 is FCCW, S1 is FCCW and Rdc is fully FCCW/OFF.
3. Plug into a 115-vac source and rotate VA1 QUARTER range. Apply power via rotating S1/RFreq control until it clicks on noting that the NEON1 indicator lamp comes on. Note: Units made before Jan 2013. NEON1 lamp only comes on when VA1 is set for above 60 vac
4. Slowly adjust S1/RFreq until the display or meter starts to activate. IMPORTANT! This adjustment tunes the load capacitance to the unit’s intrinsic leakage inductance of the output transformer and should be cautiously set to a peak reading. It preferably should be set on the CCW side of the peak meter reading. Note that the S1/RFreq control increases frequency in the CCW direction. Now slowly rotate VA1 CW noting desired effect. Note reading on the AMP meter for reference.
5. Repeat step 4 if necessary for required effect.
6. You may switch the HI/LO to HI for more power if output is below .5 amps in the LO position. Do not allow to exceed 3 amps and check transformer and circuit for heating and any excessive corona around transformer or leads.
7. Now set Rdc to the desired current reading or display texture. Some loads may cause premature shutdown in using Rdc.
Special Notes
Always check the output transformer for excessive heating, corona or arcing preferably in the dark. Do not allow to operate in this state as the transformer will burn out. It may take 30 minutes for transformer to overheat. *How ever if you burn out the transformer it is easily replaced and readily available*

Even though the output lead is rated **over 20 kV**, it must be clear of all conductive objects to prevent high frequency/voltage breakdown.

Certain loads may have different Q factors that will affect operation. Q factors is determined by the ratio of circuit reactance to resistance of the load. Reactance being the inductive and capacitive values at resonance. The resistance part is determined by your load resistance, component losses and the amount of useful corona or plasma ionization or whatever it is you need. *It might be wise to refresh your “j” operator or polar notation math skills*

Always attempt to operate **RF freq just slightly** below the current peak as indicated on the AMP meter. This is especially important when operating above 2 amps to avoid overheating the switching transistors.

**CAUTION: Contact with the bare metal controls and other objects may cause annoying burns. This is especially noticeable when powering single ended plasma displays that are within several meters of the user. Insulated tubing may be placed on the control shafts to help avoid these annoying shocks and burns.**

NOTE

**Resonant Rise Please Read as This is Important for proper operation of this product!!!**

Please note that the voltage that this unit will generate is **not a function of the turn’s ratio on the transformer**. We set the transformer to usually produce a voltage of **>30,000 V pk-pk**. The transformer secondary circuit mathematically is equated as a voltage source driving an inductive reactance. This reactance is controlled by the airgap in the secondary only of the transformer, the number of turns, and the frequency that you happen to be tuning to. This is the inductance part of the resonant system that tunes out the capacitive reactance of your load. Now when you connect this to your load which is capacitive you're going to tune the frequency and obtain a resonant rise in voltage that is going to be dependent on the Q of the circuit you are driving. So now the voltage output is a function of these parameters. You now control the voltage with the voltage control that is on the unit to prevent a potential transformer failure.

Our higher powered units have built-in protection circuitry that will shut the system down should the voltage on the transformer exceed the rating the transformer is insulated for. Usually this is at **least 30KV pk-pk, 15KV pk, >11KV rms** as at resonance wave-shape is sinusoidal. *These are conservative ratings*
This plasma driver system can drive both non resonant resistive and complex resonant loads.

**Resistive Non-Resonant Loads**

The advantage of a *straight resistive* load is that the amount of voltage the load sees is dictated by the turn’s ratio of the transformer. The current drawn is a function of the real resistance of the load and the Inductive reactance of $XL$ as the frequency that the unit is tuned to. Now the current will vary as the frequency is changed because the transformer secondary is basically a reactants and therefore the source impedance increases as you increase the frequency and vice versa as you decrease the frequency. The equivalent circuit for this approach is shown below.

\[ V = \sin(\omega t) \]
\[ XL = (f) \omega t \]

Max power occurs when $R_{load} = XL$

$XL$ increases with frequency and vice versa. This is not a resonant function but is dependent on turns ratio of transformer and freq of $XL$. This is a very useful feature controlling load power by only changing the frequency control!

The reactance also limits the short circuit current to a safe value and is all reactive energy.

*A good example of a resistive load is gas vessels with internal electrodes in direct contact with the plasma gases to be energized.*

**Complex Resonant Loads**

*A complex load* is usually capacitive in nature due to the structure of the plasma cells and containment geometries. This now presents a different problem as to get any current into the system requires that the capacitive part of the load be eliminated, and this is accomplished by varying the frequency of the generator to a point where the capacitive reactants of the load equals the inductive reactants of the secondary coil being the voltage source. The system is designed so that it works with many of the requirements that customers and experimenters have for cell structure
usually being somewhere between 10 and 200pF. Note the system is not limited to those values and can have an optional transformer made to tune out higher values of capacitance.

The amount of real power is the actual plasma or and Corona discharge formed in the real resistance of the load. The capacitive electrodes used in the geometry of the plasma structure as the capacitive part of the load and now produces a complex impedance when written in complex form is \((R-Jx)\) see drawing schematic. When the cell of the containment structure capacitance is tuned out you will get a voltage peak from a resonant rise. The only limiting factor controlling the current now is the real resistance of the load. This can take on a range of values dependent on the Q factor of the load. This function has much to do with the amount of power that can be taken without exceeding the voltages or the ratings of the transformer. This is a series resonant system when tuned therefore unlike anti-resonance or a parallel circuit, the lower the resistance the higher the Q, as equal to \(X/R\). So basically, the power that you can deliver to your system depends a lot on the values you choose for your load. However because the frequency of this unit can tune from 20 to almost 100 kHz it does give you a factor of controlling these parameters to a great extent.

One of the features of this unit is a current control by adjustment of the duty cycle. This feature allows your load to see the same voltage however it will be chopped so that when integrated over a period, the power will be controlled by the ratio of time on to time off and of course this allows tremendous flexibility when you have loads that want to draw high amounts of current over the ratings of the units.

\[ V = \sin(\omega t) \]

\[ XL/XC = (f)wt \]

Max power to \(R\) occurs when \(-XC = +XL\)

As you adjust the frequency, a point will occur where you will get a sharp rise in current as noted on the ammeter. This is where the \(-XC = +XL\) as a \((f)wt\) and cancels out leaving only the \(R\) allowing more current/power to the load dependent on the circuit Q.

Impedance of resonant as a \(f(1/t)\)

\[ Z = (X^2 + R^2)^{1/2} \quad Q = X/R \]

**NOTE:** Care must be taken when first tuning for the resonance peak. Start with the input voltage at 20%. Make adjustment between the duty cycle control and input voltage. You can damage your load or the unit if overpowered!
ADDENDUM: Example letter to customer

The specifications that you have required on your order can be met. However, at a higher frequency than 70 kHz you may not be able to get the full 2000 Watts. This power supply is primarily designed to drive resonant loads where the real resistance in the complex impedance expressed in complex form (R + JX). The amount of power that can be drawn will be a function of the circuit (Q) of your resonant circuit. So, there are certain variables that the user must be familiar with to operate this unit to its full extent. We have tried in the instructions, explain to the user these basic functions. There are several hundred of these out in the tech field without problems once the user is shown or becomes knowledgeable of complex impedances.

The power supply can also be operated in the non-resonant mode when driving virtually a pure resistance load and will operate throughout a wide band of frequencies only dropping off at the higher frequencies due to the inductive reactants of the driver transformer.

In the resonant mode of operation, these devices have the capability to tune out the capacitance of the cell or plasma container. This feature produces a resonant rise in current now allowing efficient power transfer to the real resistance of the load being the energy transferred to the actual plasma. When operated in this resonant mode the voltage generated is not a function of the turns ratio of the transformer. These transformers have been set to produce a maximum voltage of 10 to 20,000 V rms by the turns ratio. In resonant operation the transformer secondary circuit mathematically is equated as a voltage source driving an inductive reactance. This reactance is controlled by the airgap in the secondary, the number of turns, and the selected operating frequency. Now the inductance part of the resonant system tunes out the capacitive reactance of the load by adjusting the frequency control. When connected to a capacitive load the frequency should be tuned to obtain a resonant rise in voltage that is going to be dependent on the Q of the circuit being driven. So now the voltage output can be a function of these parameters and be considerably more than what is available when operated in the conventional un-tuned mode! The duty cycle control adjusts the current. See Duty Cycle download for more information.

A certain amount of knowledge helps to effectively operate the unit as in some cases it must be tuned to the output capacitance and resistance of the load. This is basic boilerplate technology to any electronics engineer and simply involves the handling of complex numbers, polar notation or simple impedance matching algebraic formulas.
Duty Cycle

Our duty cycle-controlled power has many advantages over other methods of power distribution. When power is controlled by a variac or other voltage reducing mechanisms, output to the load decreases by Ohms Law where power = E x I, and the load sees a reduced voltage to control power. Both voltage and amps are simultaneously decreased as they are dependent functions on one another. An example is in attempting to dim a gas discharge tube such as a piece of neon or fluorescent tubing. As the voltage is decreased the tube dims to a point where now the gas discharge pulls from the ends or extinguishes. Loads such as HHO reaction cells, corona or ozone production, paint spraying, flocking, or other chemical reactions suffer simultaneous voltage and current changing as dictated by the load resistance.

Duty cycled controlled power utilizes the time domain of the voltage. The waveform sketches show various ratios of the voltage wave form over a 1 second period. The sketch at A shows 10 volts at 100% “time on.” The power produced in a 5-ohm resistor is simply volt squared divided by load resistance, in this case 10^2/5=20 watts. Sketch B shows a 50% “time on.” One might think that the power is now 10 watts…but this is WRONG! For the 1-second period the voltage is discontinuous. It is 10 volts for half the 1 sec period and zero for the other half. The load sees full voltage and full current therefore full power of 20 watt for 1/2 sec. The energy for the one sec period is 5 joules. As the time “on” decreases the load still sees full voltage for the “on” interval, but now proportionately less energy in joules.

A plasma such as ionized neon gas in a long glass tube clearly shows this neat effect. The display can be reduced to a snake like thin line of energized plasma. The plasma would not pull from the ends of the discharge tube but would be obviously very dim. This is the result of very short full voltage pulses at corresponding current but much less joulean energy as energy = \int v(t)

The load (if a gas discharge tube, solid state Tesla coil, HHO gas generator or those mentioned above) will now maintain the operational benefit of full voltage intervals but greatly reduced energy due to the shorter time “on”.

If you dimmed the same tube by reducing the entire voltage time domain you would get dimming with display pulling away from the end electrodes and becoming very inhomogeneous. Other devices would function very erratically due the lack of voltage during the “on” time of the period.

To summarize: you can control the power to a device by control of the current without reduction of the applied voltage. The device operates at normal voltage and current for a variable domain in time

<table>
<thead>
<tr>
<th>100% duty cycle</th>
<th>50% duty cycle</th>
<th>25% duty cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 VOLT LEVEL FOR 1 SEC INTO 5 OHM LOAD P=20 WATTS</td>
<td>10 VOLT LEVEL FOR 5 SEC INTO 5 OHM LOAD P= 5 WATTS</td>
<td>10 VOLT LEVEL FOR 25 SEC INTO 5 OHM LOAD P=1.25WATTS</td>
</tr>
</tbody>
</table>
TRANSFORMER RESONANT SPECIFICATIONS FOR THOSE WHO WISH TO USE FOR HIGHER LOAD CAPACITY UP TO >1µFD

Transformers use our own standard tooled UU69 ferrite core with the following specs: CORE is 69 x 39 x 23 mm, $u=2000$ $Ae=2.3$ cm sq $Le=22.9$

Approximate Values for Load Capacity 2500 Turn Included Bobbin  

<table>
<thead>
<tr>
<th>TURNS</th>
<th>GAP</th>
<th>L</th>
<th>XL</th>
<th>FREQ</th>
<th>APPROX C TO RESONATE AT FREQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 turns 2 gap =16.5 H (6.2M)@60kHz</td>
<td>.04 pfd</td>
<td>Self resonant/60kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 4 mil gap =8.5 H(3.2M)@60kHz</td>
<td>.31pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 8 mil gap =5.7 H(2.1M)@60kHz</td>
<td>.46 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 20 mil gap =2.9H(1M)@60kHz</td>
<td>.91 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 2 gap =16.5 H (2.07M)@20kHz</td>
<td>3.8 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 4 mil gap =8.5 H(1.06m)@20kHz</td>
<td>7.5 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 8 mil gap =5.7 H(.72M)@20kHz</td>
<td>11 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500 turns 20 mil gap =2.9H(.36M)@20kHz</td>
<td>22 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximate Values for Load Capacity 1000 Turn Optional Bobbin

<table>
<thead>
<tr>
<th>TURNS</th>
<th>GAP</th>
<th>L</th>
<th>XL</th>
<th>FREQ</th>
<th>APPROX C TO RESONATE AT FREQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 turns 2 gap =2.6 H(+j.98M)@60kHz</td>
<td>2.7 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 4 mil gap = 1.36 H(+j.51M)@60kHz</td>
<td>5 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 8 mil gap =.9 H(+j.34M)@60kHz</td>
<td>7.8 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 20 mil gap =.46 H(+j.17M)@60kHz</td>
<td>15 pfd/60kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 2 gap =2.6 H(+j.33M)@20kHz</td>
<td>24 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 4 mil gap = 1.36 H(+j.17M)@20kHz</td>
<td>46 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 8 mil gap =.9 H(+j.11M)@20kHz</td>
<td>70 pfd/20kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 turns 20 mil gap =.46 H(.j05M)@20kHz</td>
<td>250 pfd/20kHz</td>
<td></td>
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</tr>
</tbody>
</table>

The above possible combination of the 1000 turn coil combined with the adjustable frequency of from 20 to 64 kHz allow resonating any capacitive cell from 2.7 to 250 pfd and provides plenty overlap by just changing the airgap in the secondary of the transformer.
TRANSFORMERS with the 1000 potted turns or 2500 potted turns secondary coil will have 2 mils air gap per side. You may take apart and change the gap on the secondary side **ONLY** to bring larger load capacities within tuning range. Leads must be as short as possible for low capacitive loads <2.5 pfd.

We have roughly calculated transformer secondary turns at the frequencies of 20 to 65 kHz for those who need to go 1nf, 10nf 100nf and >1ufd. These are the following optionally available coils covering all ranges. The 2500 potted coil is supplied with all units. Hand wound coils are easily pruned by removing or adding turns.

**Other available secondary coils for suggested ranges of load capacitance**

Similar looking to the FLYPVM400 but intended for resonant operation. 30kV peak pk at 20ma, 15kHz-60kHz operating frequency, with 3" size large ferrite core and flexible silicon output lead. 2500 turns #35 on secondary with silicon output lead. Primary is included. UU69 large core is air gapped and can easily be adjusted to change the resonant frequency and is noted on the PVM500 instructions. Output voltage will vary as to the external load complexity being the load capacity and resistance. For end point grounded circuits. (We can manufacture these, and variations, in large volume for the trade -- contact us for details.)

- **4000 turn secondary coil bobbin only for replacement.** For non-resonant where electrodes are in direct contact with plasma SKU# COIL4000L... $49.50
- **2500 turn secondary coil bobbin only for replacement.** See Above Spec Chart on Ranges of Load Capacity SKU# COIL2500L... $49.50
- **1000 turn secondary coil only for replacement.** See Above Spec Chart on Ranges of Load Capacity SKU# COIL1000L... $49.50
- **560 turns coil non potted hand wound** coil tunes 100 to 1000 pfd between 20 to 65 Khz. Coil Bobbin only SKU# COIL560... $49.50

Please take note that the maximum voltage across a capacitive load is a function of the circuit Q and can peak to levels that can destroy the load under test, output transformer and associated circuitry. Therefore, the unit in not totally “user friendly” and is intended for use by those experienced in powering up these resonant capacitive loads. Caution as the output transformer can be easily damaged if allowed to spark over encapsulation.
The circuit shown in blue is a modification made to these units after March 2014. It is for monitoring the frequency of the unit and is totally isolated from any of the circuit power. Output voltage is around 10 V but may vary. Wave shape is square.
FLYPVM-series Potted & Unpotted Secondary Coils

Price: $49.50
SKU: COIL2500

Product Description

We have a selection of different potted & unpotted coils for the PVM500 (these coils can also be used on the DIDRIV10 and DIDRIV10HHO). Coils are rated **very conservatively** at 30KV peak to peak and are end point grounded.
We have roughly calculated transformer secondary turns at the frequencies of 20 to 65 kHz for those who need to go 1pf, 10pf, 100pf and >1000pf. These are the following optionally available coils covering all ranges.

*Please note that the capacitance ratings here are for the coils by themselves, and once the coils are put into a power supply (like the PVM500) the tunable ranges will *slightly change* according to the properties of the power supply -- so for the parameters of these coils operating in the PVM500, please refer to the capacitance ranges noted on the corresponding version of the PVM500.*

COIL4000L: epoxy potted coil of 4000 turns for conventional (non-resonant) loads, such as when electrodes are in direct contact with the plasma gas

COIL2500L: epoxy potted coil of 2500 turns, a slightly larger coil able to be driven to slightly larger powers

COIL1000L: epoxy potted coil of 1000 turns, a slightly larger coil able to be driven to slightly larger powers

**COIL560: non-potted hand wound coil of 560 turns, tunes 100 to 1000 pfd between 20 to 65 kHz:** The non-potted hand wound coils are easily modified by removing or adding turns. The other coils of less turns are made from modifying the 560-turn coil. You must be aware that as these turns are removed the operation of the unit may become unstable and erratic as the circuit Q is approaching “no mans land”

Please note, you may find some discrepancies and conflicts in the measurements our engineers took with some of the coil parameters. None of them are off by that much and we did leave them in place on these instructions. If you find you need to question one of these conflicts, please contact us and we will resolve the issue for you. But again, none of these, I believe are serious enough to cause a major problem in setting the unit up.

Regards Bob and team