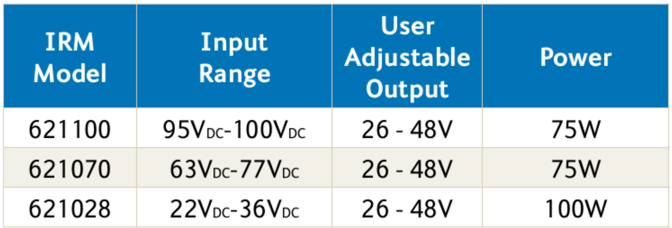
Power Distribution Module (PDMs) Design Guide – 5-5-17

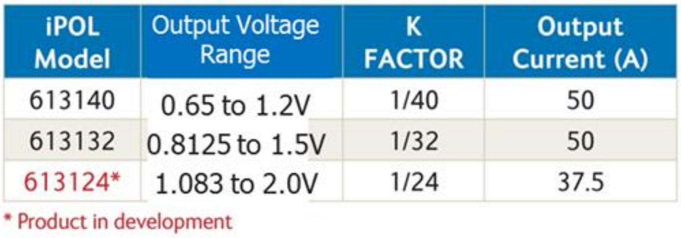
Introduction

Designing with Cobham PDMs is extremely quick and easy once you learn the basics. The interchangeable modular approach to power system design reduces NRE costs and schedule, with greater flexibility later in your program when requirement changes can be the most impactful. This design guide teaches you the all the basics you will need, from architecting your power system, how to analyze your system AC and DC performance, as well as designing EMI filtering for PDMs. Table 1 shows you the Cobham offering of PDM modules.

TABLE 1: Cobham PDM Products

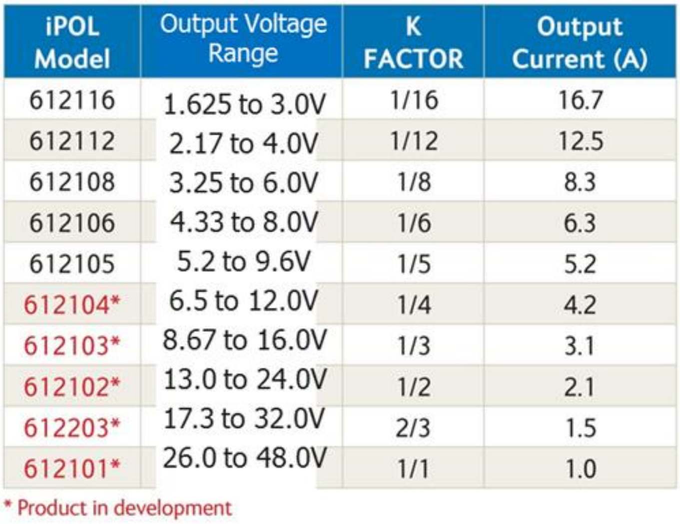


IRM Model	Input Range	User Adjustable Output	Power
621100	$95V_{DC}$-$100V_{DC}$	26 - 48V	75W
621070	$63V_{DC}$-$77V_{DC}$	26 - 48V	75W
621028	$22V_{DC}$-$36V_{DC}$	26 - 48V	100W



iPOL Model	Output Voltage Range	K FACTOR	Output Current (A)
613140	0.65 to 1.2V	1/40	50
613132	0.8125 to 1.5V	1/32	50
613124*	1.083 to 2.0V	1/24	37.5

* Product in development



iPOL Model	Output Voltage Range	K FACTOR	Output Current (A)
612116	1.625 to 3.0V	1/16	16.7
612112	2.17 to 4.0V	1/12	12.5
612108	3.25 to 6.0V	1/8	8.3
612106	4.33 to 8.0V	1/6	6.3
612105	5.2 to 9.6V	1/5	5.2
612104*	6.5 to 12.0V	1/4	4.2
612103*	8.67 to 16.0V	1/3	3.1
612102*	13.0 to 24.0V	1/2	2.1
612203*	17.3 to 32.0V	2/3	1.5
612101*	26.0 to 48.0V	1/1	1.0

* Product in development

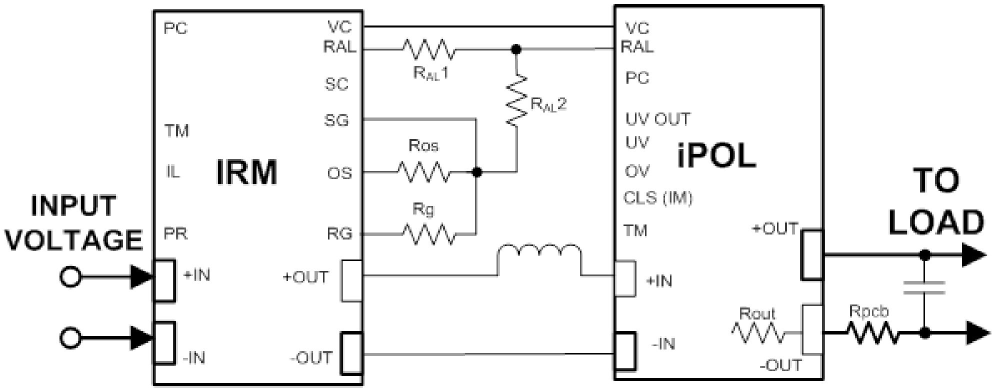


Figure 1: Basic IRM and iPOL Connections

System Architecture

When designing with PDMs, it is assumed that the following requirements are known: Input voltage range, required output voltages and tolerances, and load currents (at least a maximum). Other requirements that may influence the architecture are: specific efficiency requirements, unusual transient requirements, and sequencing requirements.

The simplest design approach is to use a single IRM and a single iPOL to produce each voltage required. For each output voltage required, select an iPOL using the following the equation:

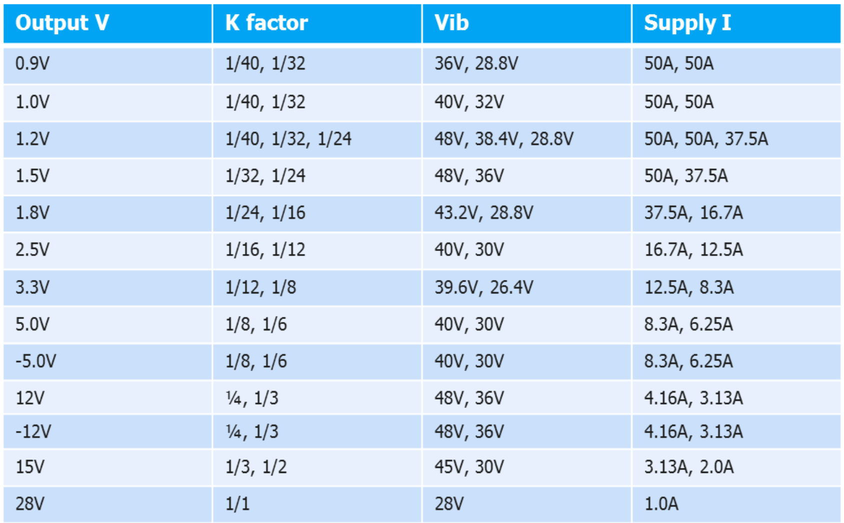
Vib = Vout / K;

Where Vib is the intermediate bus voltage which is the output voltage of the IRM, Vout is the required voltage and K is the K factor of iPOL. **Note:** Vib needs to be between 26 and 48V for proper use of the IRM. See Table 2 for a list of common user voltages and the K factors that produce the Vib within the IRM output voltage range.

Once the iPOL is chosen only two resistor values need to be calculated, R_{OS} and Rg. The equation for R_{OS} is found in the IRM datasheet and the calculation for Rg is found in anpdm100 (**Note:** The values of $R_{AL}1$ and $R_{AL}2$ are found in anpdm100 as well).

Finally, choose your IRM based on your input voltage range. The values of R_{OS} and Rg remain the same for each of the IRMs. At this point, the calculations for the design of a DC-DC converter are complete.

TABLE 2: Common Output Voltages and iPOL output currents



Output V	K factor	Vib	Supply I
0.9V	1/40, 1/32	36V, 28.8V	50A, 50A
1.0V	1/40, 1/32	40V, 32V	50A, 50A
1.2V	1/40, 1/32, 1/24	48V, 38.4V, 28.8V	50A, 50A, 37.5A
1.5V	1/32, 1/24	48V, 36V	50A, 37.5A
1.8V	1/24, 1/16	43.2V, 28.8V	37.5A, 16.7A
2.5V	1/16, 1/12	40V, 30V	16.7A, 12.5A
3.3V	1/12, 1/8	39.6V, 26.4V	12.5A, 8.3A
5.0V	1/8, 1/6	40V, 30V	8.3A, 6.25A
-5.0V	1/8, 1/6	40V, 30V	8.3A, 6.25A
12V	¼, 1/3	48V, 36V	4.16A, 3.13A
-12V	¼, 1/3	48V, 36V	4.16A, 3.13A
15V	1/3, 1/2	45V, 30V	3.13A, 2.0A
28V	1/1	28V	1.0A

Notice for most output voltages, more than one type of iPOL can be chosen. This flexibility allows designers the ability to choose an iPOL that is the most efficient for an application or choose iPOLs that utilize the same intermediate bus voltage so that a single IRM can be used to produce multiple output voltages.

When designing a system that uses multiple iPOLs with a single IRM, the difference is in the way the Rg resistor is calculated. The next section covers these types of architectures.

Adaptive Loop

The adaptive loop is the PDM way for compensating for voltage drops across resistive elements in the load current path from the IRM output to the load. These elements include the iPOL (which is specified by the ROUT limits of the datasheets), the iPOL output to load printed circuit board resistance and any series resistance such as connectors or inductors in the load current path. Typically, the resistance elements between the IRM and the iPOL can be viewed as negligible, although they can be added to the iPOL ROUT value by reflecting the impedance to the secondary side by dividing the resistance by the square of the iPOL K factor.

The adaptive loop works by sensing the return current from the iPOLs through the IRM –OUT connections. As the load increases, the sensed current increases. Rg sets the gain of the compensation.

When multiple iPOLs are used with a single IRM, the calculation of Rg must take into account the various resistive elements of multiple iPOLs as well as the current load contributions of each iPOL. The following are typical connections of multiple iPOLs to a single IRM.

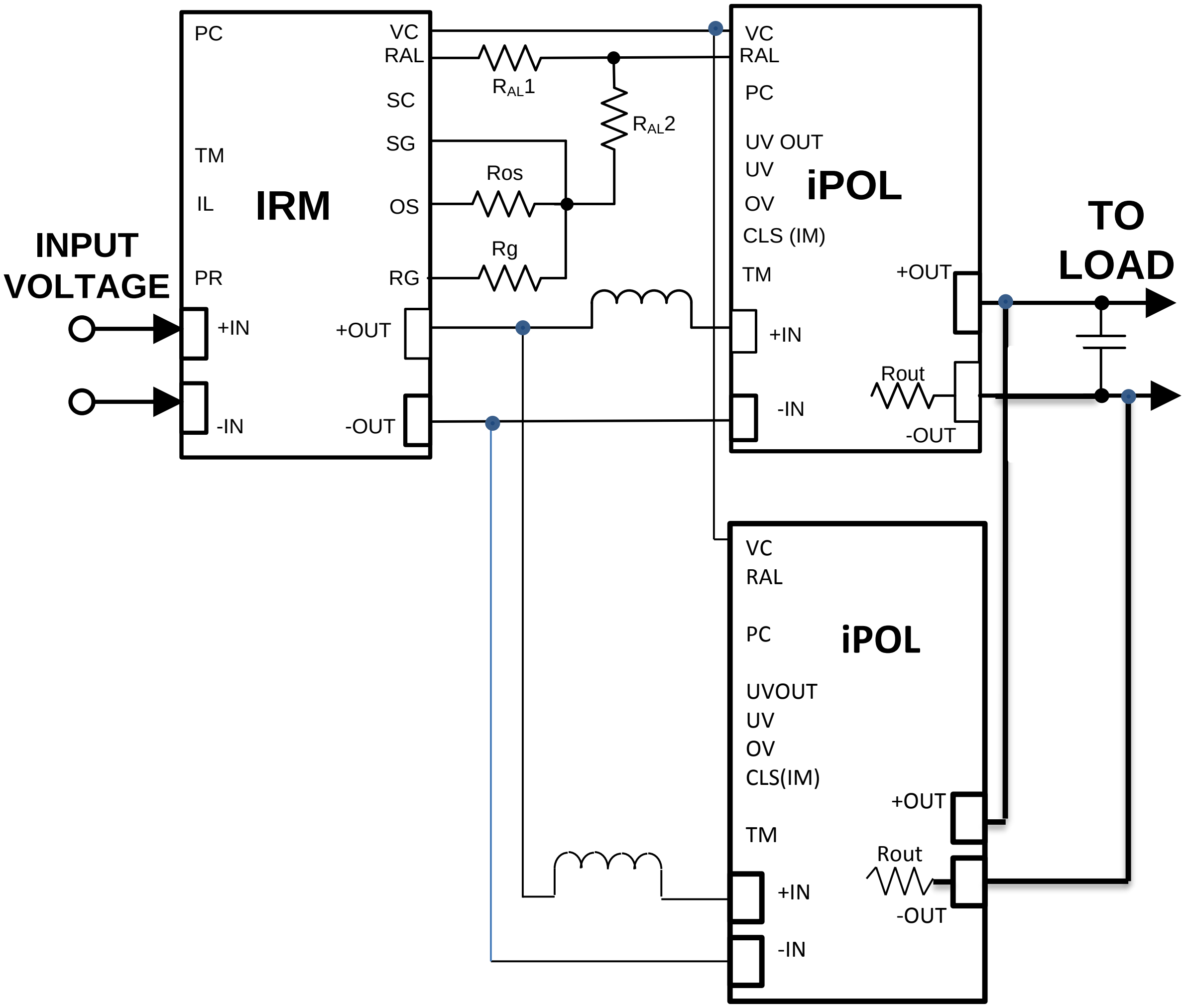


FIGURE 2: ADAPTIVE LOOP with Parallel iPOLs

When the need for load current exceeds the limit of a single iPOL, then parallel iPOLs with a single IRM can be used to meet the demand (as long as the power demand does not exceed the limit of the IRM). In this case, the Rout values of each iPOL form parallel impedance, reducing the compensation required. Since both iPOLs have the same typical Rout, then the parallel combination yields Rout/2.

$$\text{Comp} = 1.1 * (\text{Rout}/2 + \text{Rpcb}) * (1/K) / \text{Vout}$$

The calculation for Rg remains the same (see anpdm100).

Because only one iPOL can be monitored thermally, then the slight variation in temperature between iPOLs (assuming they are mounted on the same PWB with equivalent mounting surface temperature) will be negligible. Be sure to only connect the IRM RAL output to only a single iPOL as shown in Figure 2.

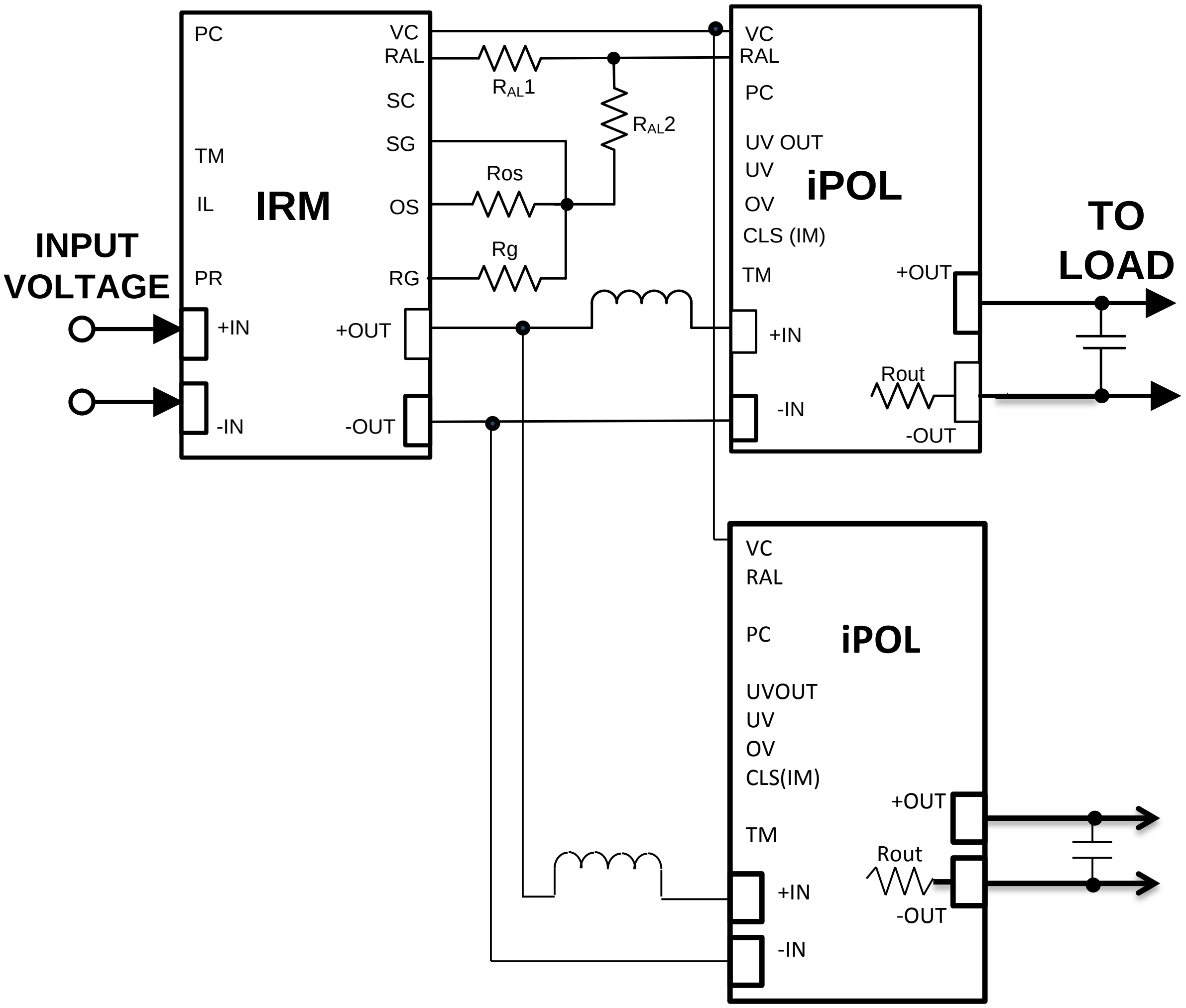


Figure 3: Adaptive Loop with Multiple iPOLs not in Parallel

When connecting iPOLs of differing K-factor to a single IRM, the accuracy of the adaptive loop will be impacted. This is because each iPOL may require a different magnitude of compensation and the adaptive loop current is the sum of all the iPOL currents. Remember, the sum of all the iPOL loads must not exceed the IRM output load power limit.

To calculate an initial value of Rg, calculate the compensation of each iPOL independently. Divide the sum of compensation values by the square of the number of iPOLs. Then use this value to calculate the Rg value of the IRM.

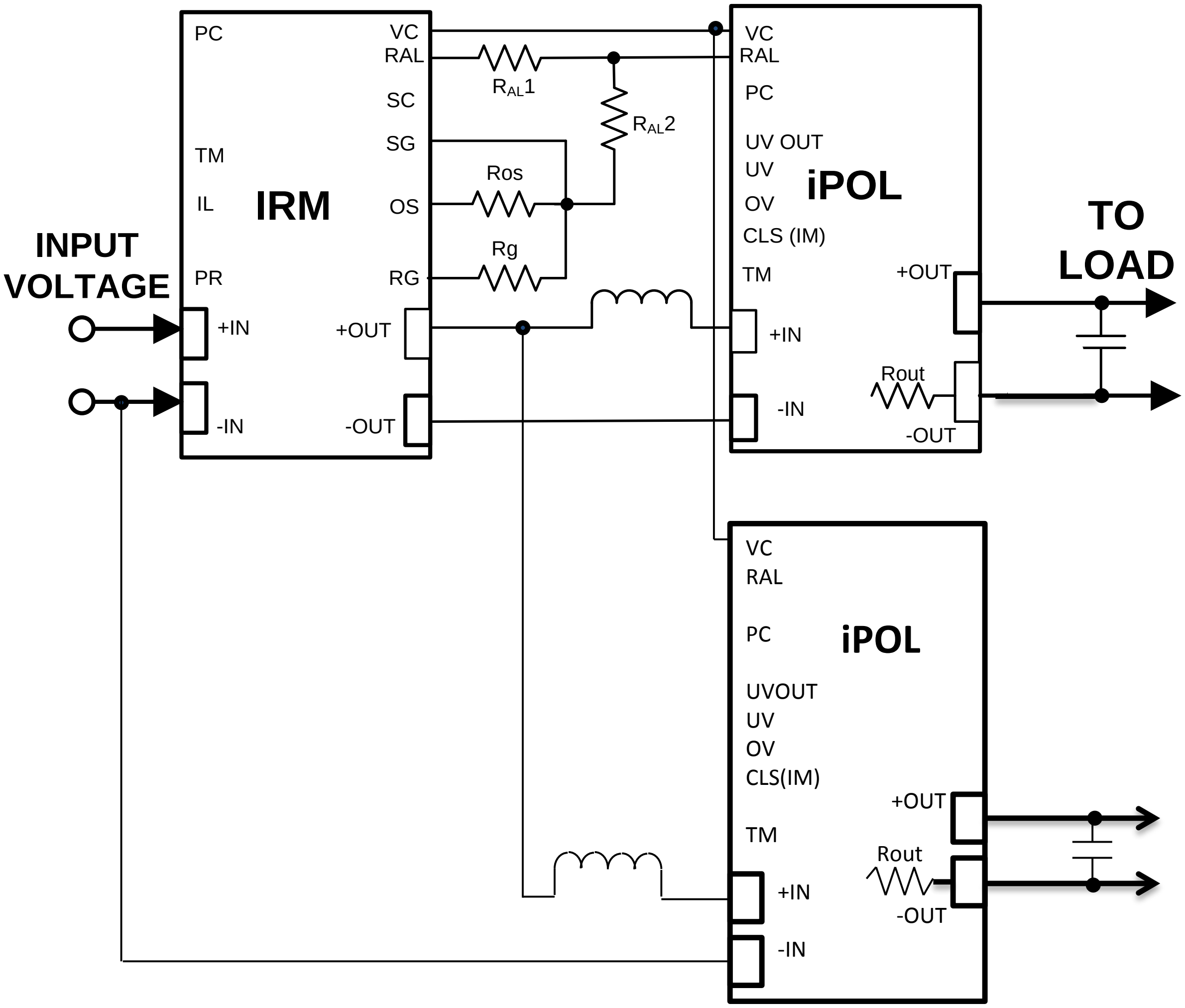


Figure 4: Modified Adaptive Loop with Multiple iPOLs

The system shown in Figure 4 allows an iPOL –IN connection to be connected directly to an IRM –IN terminal. This allows the loading of one of the iPOLs to have no effect on the adaptive loop compensation (current is sensed within the IRM on the –OUT terminal). This type connection can be useful if there is a large mismatch in loading between the two iPOLs or if one of the iPOLs does not require a highly accurate output voltage. In Figure 4, the adaptive loop gain can be set to serve only the top iPOL, while the bottom iPOL load current would not affect the IRM output voltage. The calculation of Rg would be done for only the iPOL with it's –IN connected to the IRM –OUT.

Worst case DC Performance

The DC regulation of a single IRM with a single iPOL can be better than +/-3% if the load resistance is well characterized. Tolerance of +/-3.5% can be achieved with two iPOLs of differing K factor and +/-4% with three iPOLs.

The spreadsheet "Worst Case Voltage Regulation" was created to aid in the analysis of the differing iPOL configurations. It provides both Extreme Value Analysis (EVA) and Root Sum Square (RSS) analysis for the configurations. It also allows the user to modify the Ros and Rg values to optimize the system performance.

EMI Design

The PDM architecture greatly simplifies the design of input and output EMI filters compared to traditional switching converters. Both the IRM and the iPOL are "soft switchers" meaning they do not generate high frequency switching noise and, because they operate at frequencies higher than typical converters, the size of the filters required to meet output ripple and conducted emissions requirements are drastically reduced.

The datasheet provides the maximum output ripple voltage of the iPOLs with a 40V input and maximum load current with no external capacitance. Because of the low impedance of the iPOL as a voltage source (the iPOL source impedance is approximately the Rout value of the iPOL in series with 600pH (for 613xxx modules) or 1.2nH (for 612xxx modules) and the high switching frequency of the ripple voltage, bulk tantalum capacitors by themselves do little to attenuate the output ripple. In order to achieve peak to peak output ripple voltages of less than 1% of the output voltage, a series low resistance power inductor, such as the Coilcraft SLC7649 series or XAL8080 series, in series with the iPOL output is needed. An example of a simple output filter for a 1V output is shown in Figure 5.

The IRM output ripple can be as high as 3.5% of the IRM output voltage. This carries over to the iPOL output as a function of the iPOL K factor. Because this voltage sums with the iPOL output ripple, it is important that the iPOL output filter has adequate attenuation at the IRM switching frequency (800KHz or 600KHz, depending on which IRM model is used). In Figure 5, the filter has about 12db of attenuation at 800KHz and 5db of attenuation at 600KHz. To get adequate filtering at these frequencies, a single tantalum capacitor added in parallel to the ceramic capacitors would achieve 20db of attenuation at the IRM ripple frequencies.

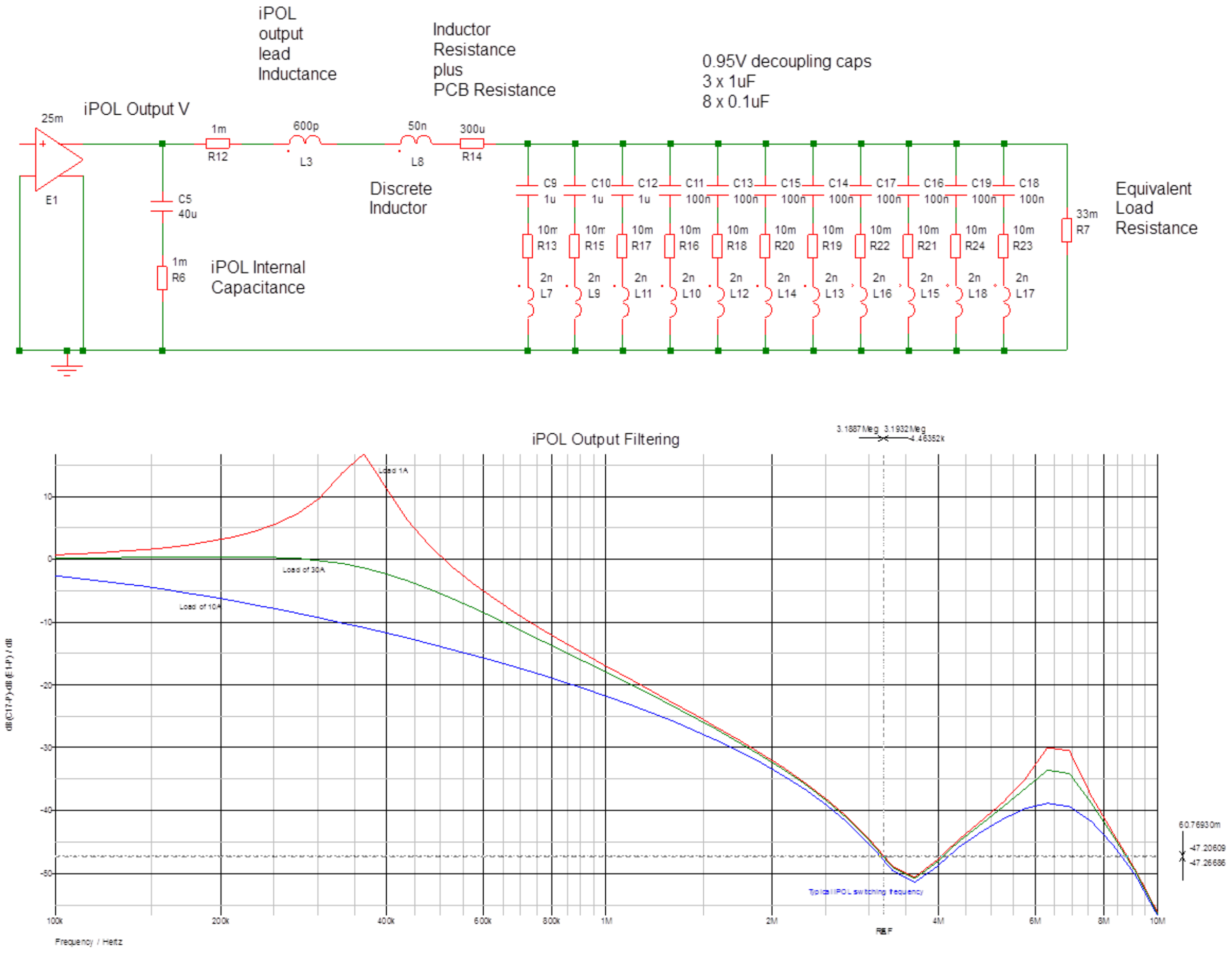


Figure 5: A simple iPOL output filter for a 613140 module with a 50nH (84A Isat, 170uohms DCR) and 3.8uF of ceramic capacitance. Greater than 40db of attenuation at iPOL switching frequency. Red trace load of 1A, Blue trace load of 10A, Green trace load of 30A.

Input filter design is made easier in this way. Each IRM specifies its input ripple current and its switching frequency. IRM current ripple is sinusoidal in shape. Because the IRMs cannot be synchronized, it is always a possibility that all IRM peaks will line up. Therefore, simply add all of the IRM input ripple current values together, compare this to your conducted emissions specification, and design your input filter to provide that much attenuation at the IRM switching frequency. Figure 6 is a sample input filter that supports 4 621028 IRMs with a total load of 200W.

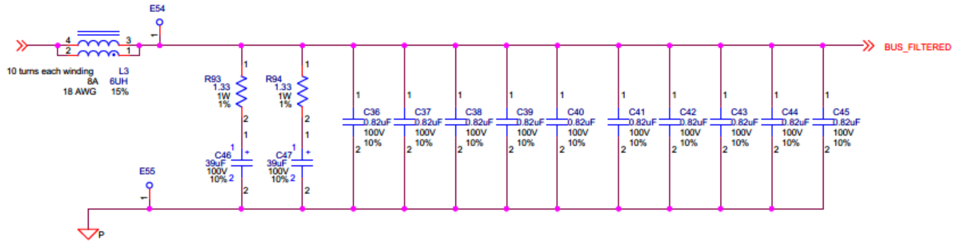


Figure 6: Sample Input Filter for 621028 IRM (4 total in system)
Provides 60db of CE ripple attenuation at 28V IRM switching frequency of 800KHz

Sequencing

Each IRM and iPOL can be individually commanded on or off, suggesting that any turn on sequence is possible. This is complicated by the fact the 613xxx iPOL should be started in VC mode and the 612xxx iPOLs should not. Therefore, when iPOLs of differing K factors are connected to a single IRM, 613xxx iPOLs will come on first. In some cases, it may be necessary to add a second iPOL in order to allow a 612xxx iPOL to come on first. **Note:** 613xxx iPOLs do not have an internal soft start circuit and utilize the IRM soft start function in VC mode; the 612xxx iPOLs do have an internal soft start circuit and can be turned on after the IRM output is at its steady state voltage without resulting in excessive inrush currents.

These guidelines are meant to aid designers in getting designs started with PDM products. Cobham's engineering team is ready to assist our customers in reaching their optimal solution. Please visit www.cobham.com/HiRel for the Power Distribution Module information or email info-ams@cobham.com.