Welcome to the Advanced Power Supply Topics Web seminar.
This is the agenda for this course. We will discuss issues that affect the reliability and saleability of switch mode power supplies.

Inrush current and soft-start functionality affect the turn-on stresses of a power supply.

Input Transients refer to externally generated excessive voltage pulses that can damage a switch mode power supply.

Low or high input supply voltages are problems handled with Under and Over Voltage Lockout functions.

Power supply output Over-voltage and Over-current conditions need to be considered.

Voltage Trimming, Remote Sense, and Power Supply Sequencing are topics that affect the output voltage at the user’s load.

In large fault tolerant systems, Load Sharing among power supply modules is required.

To sell power supplies, EMI (Electro Magnetic Interference) issues must be considered.
Inrush Limiting

Controlled charging of input capacitors

- Reduces component stress
- Implemented with:
  - NTC (Negative Temperature Coefficient Resistors)
  - TRIACs
  - Relays
  - Active PFC circuits

When a power supply is first plugged in or turned on, there is a large current surge into the power supply as the input capacitors are charged.

Current inrush causes the “arching” noise often heard when a computer or other device is first plugged into the wall socket. Current inrush is stressful on switches, diodes, capacitors, wall sockets, etc.

Many power supplies incorporate “Inrush Limiting”. The most common method is the NTC (Negative Temperature Coefficient) resistor. The NTC resistor has a high resistance (about 40 ohms) when cold and a low resistance (< 1 ohm) when hot. The NTC resistor is placed in series with the input to the power supply. The cold resistance limits the input current as the input capacitors charge up. The input current heats up the NTC and the resistance drops during normal operation.

If the power supply is quickly turned off and back on, the NTC resistor will be hot so its low resistance state will not prevent an inrush current event.

Another method is to use TRIACs or relays in parallel with a resistor. The resistor limits inrush current. A sensor circuit monitors the input capacitor voltage. When the input capacitors are charged, either a relay or a TRIAC across the input resistor is enabled to provide a path for power flow during normal operation.

Active Power Factor Correction (PFC) circuits also minimize inrush currents by minimizing the size of the input capacitors directly connected to the power input terminals.
Soft-start is the process of actively controlling the power supply so the output voltage(s) rise at a controlled rate at power-on. The soft-start process limits peak currents that normally flow to charge capacitors in the power supply and the attached load at power-on.

The controlled soft-start process reduces stresses on components and helps to reduce input current inrush.

A Hard-Start (non soft start) power-up process will generate severe current loads that cause acoustical noise from components such as transformers and capacitors that are audible to the customer.

Hard-start power supplies can experience output voltage over-shoot on start-up.
Lightning and electrical equipment on the AC power lines can generate very high voltage spikes (1 to 20 thousand volts) lasting 0.5 to 50 microseconds. There are several types of devices used to limit the input voltage transients.

1. The most common transient protection device is the MOV (Metal Oxide Semiconductor), also called a Varistor. MOVs clamp high voltages by becoming a low resistance when a high voltage is applied. MOVs are inexpensive and can absorb a lot of energy. The relatively high “on” resistance means that “clamped” voltage can still exceed a thousand volts. MOVs have a wear-out mechanism with repeated energy absorption events. They fail shorted and therefore they must be fused.

2. Transzorbs are basically power ZENER diodes. Transzorbs offer very high speed and tight voltage clamping characteristics. Transzorbs have limited energy absorption and are expensive.

3. Gas filled surge suppressors can clamp very high energy surges, but the clamping voltage may be several times their rated voltage. Once a gas filled suppressor arcs and conducts (begins clamping), they will continue to conduct until the input voltage is removed. When used on an AC power line, the alternating voltages usually commutate the arc. Gas filled devices are not used on DC power lines.

Many systems use combinations of these devices to obtain the desired surge protection.
Under / Over Voltage Lockout

- At low input voltages, current grows causing power dissipation problems.
- At high input voltages, switching transients can exceed device voltage ratings.
- At very low input voltages, supply voltage to control and transistor drive circuits is inadequate.
- In all cases, the power supply should shut down until nominal input voltages return.

Power supplies usually incorporate circuitry that inhibits the operation of the power supply if the input supply voltage is too low or too high.

Low input voltages are stressful to a power supply because the input current rises as the input voltages drop (assuming a constant load). Most AC power supplies have a lower input voltage limit of 85 VAC to prevent overheating the internal components. Excessively low input voltages can cause faulty operation of the control circuitry, and insufficient gate drive voltage to the MOSFETS and IGBTs.

High input voltages can damage transistors and other components as their voltage ratings are exceeded. Be wary of switching generated transients which at high input voltage conditions may exceed the transistor specifications.

When the input voltage to a power supply is out of specification, the safest response is to turn off the power supply until input conditions improve.
Over voltage circuits provide protection for the load in the advent of a failure in the power supply.

A “Crow-Bar” circuit typically includes a Silicon Controlled Rectifier (SCR), a fuse, and a voltage sensing circuit.

If an over voltage is detected, the SCR is turned on to a conducting state and current from the power supply flows through the fuse and SCR into the power return line (ground).

The fuse is sized to blow at the maximum current rating for the power supply, but not at the normal current load experienced by a functional system.

Fuse tolerances are quite wide, so the power supply must be rated for more current than required by the load to insure that the fuse will blow when the “Crow-Bar” is activated.

The cost of providing a crow-bar circuit, and associated cost of a power supply with a higher current rating, must be weighed against the cost of destroying the “LOAD” if a power supply failure occurs.
Over Current Fault Response

- Immediate Shut down
- Delayed shutdown
- Constant Current Limiting
- Constant Power Limiting

There are four basic behaviors a power supply can provide in response to an over current situation:

1. The power supply can immediately shut down and then periodically check to see if power can be restored. (Auto-Restart).

2. The power supply can tolerate the overload for a period of time before it shuts down (perhaps a few minutes, it is thermally limited).

3. The power supply can enter a current limited mode. The full rated current is delivered to the load. The output voltage is determined by the load current and the impedance of the load. An issue with this response methodology is that the power supply is providing high power to a load that may have experienced a failure. This could become a fire hazard.

4. The power supply enters a power limited mode. The output voltage is reduced (but controlled) as the output current grows. The goal is to limit thermal overload. This mode is useful where the load can tolerate a voltage drop.
Voltage trimming is often supplied on a power supply to enable the user to adjust the output voltage slightly to compensate for system wiring voltage drops or to compensate for unit to unit variations of the power supply.

The voltage trimming is usually implemented with a potentiometer (variable resistor) that the user adjusts with a screwdriver.
Remote sensing uses additional wires from the power supply to the load to sense the voltage at the load. These sense wires are called “Kelvin” connections. No appreciable current flows through them so they do not experience any significant voltages drops.

Remote sensing compensates for voltage drops across the system wiring between the power supply and the load.

The remotely sensed voltage modifies the power supply output voltage over a limited range (typically +-3%). The voltage adjustment range is usually limited to insure that an open remote sense circuit does not produce excessive output voltages that might damage the load.
Many electronic devices require their multiple supply voltages be coordinated at power on and off to protect their circuitry.

If the supply voltages are improperly applied, many integrated circuits can experience “Latch-up”, a destructive process where internal semiconductor junctions become forward biased resulting in uncontrolled current flow.

Other systems require that specific circuitry be powered prior (to put it in a known safe state) to the rest of the load circuitry.

The most common power supply sequencing method is the simultaneous ramp up and down.

The choice of power sequencing is very dependent on the system requirements.
Load sharing connects the outputs of two or more power supplies together to power a load. Usually there are more modules with more total power capability than required by a system. The amount of “redundancy” is dictated by system reliability goals.

If a power supply module fails, the remaining modules continue supplying power to the system. The user can remove failed modules and install a replacements without powering down the system.

Load sharing is often a requirement for large computer system power supplies where fault tolerance and high system reliability is a necessity.

Ideally, all of the modules should share the load equally. By operating at reduced workload (assuming redundant capacity), the reliability of the power modules will be increased.

Slight differences in component values and wiring resistances causes the output voltage of some modules to be slightly higher than others. Even if the voltage imbalance is only millivolts, the result is some modules “hog” the load while others are lightly loaded.

The heavily loaded modules run hotter and will probably fail earlier, the remainder carry more load and then they fail, geating a “Domino” effect.

A slow analog or digital communications link passes information among the modules to force the output voltages to a common value to enforce load sharing. The control loop is slow, working on a thermal time constant basis.
Around the world there are many government agencies and standards bodies that regulate conducted and radiated emissions of electronic equipment. Europe, with the rise of the EU is migrating to a unified IEC standards. Consult with experts on what the applicable limits are for your markets.

The Switch Mode Power Supply with its high frequency switching and high power levels is by nature a powerful emitter of radio frequency noise. The chart shown in this slide is illustrative of the typical limits imposed on power supply designers and manufacturers.

When the tests are performed, the RFI receiver has a fixed bandwidth, typically 9 KHz wide when scanning from 150 KHz to 30 MHz, and 220 Hz when scanning below 150 KHz.

The limited measurement bandwidth is important in understanding the value of dithering (spreading) the noise emissions over a wide frequency range to reduce the average noise power per Hertz of bandwidth. While the total emitted noise energy does not change, the measured peak values will be reduced.
EMI filters for switch mode power supplies typically include circuit elements to attenuate both common mode and differential noise.

The most common low cost filters incorporate the "Xcap" (for differential mode noise suppression), the common mode choke, and the "Ycap" (for common mode noise suppression).

For applications that require more attenuation of EMI, complex filter designs incorporate multiple instantiations of common mode and differential filter elements.

The "Ycap" enables AC current flow into the ground connection. This current is called "Ground Leakage".

The "Ycap" ground leakage is an issue in medical applications where ground leakages must be kept very small.
Safety agencies have standards (such as IEC-950, and UL-1950) that limit ground leakage currents to levels that are considered safe for the general public. The major contributor to ground leakage currents are the common mode filter capacitors called “Ycaps”.

The need to limit ground leakage current limits the minimum impedance of the “Y” capacitors and therefore their effectiveness in combating common mode noise.

The medical equipment has much lower limits (IEC-601, and UL-2601) because equipment may be connected directly to patient internal organs thus bypassing the skin resistance. Leakage currents can cause heart defibrillation.

Meeting medical leakage current requirements can be difficult because the parasitic capacitances between circuit components and the enclosures can add significant leakage currents.
Key Support Documents

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<tr>
<td>General Purpose and Sensor Family Data Sheet</td>
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<td>dsPIC30F Family Overview</td>
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<tr>
<th>Base Design Reference</th>
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<tr>
<td>dsPIC30F Family Reference Manual</td>
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<td>dsPIC® Language Tools Libraries</td>
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For more information, here are references to some important documents that contain a lot of information about the dsPIC30F family of devices.

For device data sheets, Family Reference Manuals, and other related documents please visit the following Microchip websites.
Thank you for attending this seminar.