**Linear versus switch-mode power supplies**

**Introduction**

Linear power supplies were the mainstay of power conversion until the late 1970’s when the first commercial switch-mode became available. Now apart from very low power wall mount linear power supplies used for powering consumer items like cell phones and toys, switch-mode power supplies are dominant.

**So what is the difference in how they work? – (Techy stuff)**

Linear power supplies have a bulky steel or iron laminated transformer. This transformer has two purposes - It provides a safety barrier for the low voltage output from the AC input and reduces the input from typically 115V or 230VAC to a much lower voltage around say 30VAC.

The low voltage AC output from the transformer is then rectified by two or four diodes and smoothed into low voltage DC by large electrolytic capacitors.

That low voltage DC is then regulated into the output voltage of choice by a dropping the difference in voltage across transistor or IC (the shunt regulator).

Switch-mode supplies are a lot more complicated. The 115V or 230VAC voltage is rectified and smoothed by diodes and capacitors resulting in a high voltage DC. That DC is then converted into a safe, low voltage, high frequency (typically switching at 100kHz to 500kHz) voltage using a much smaller ferrite transformer and FETs or transistors. That voltage is then converted into the DC output voltage of choice by another set of diodes, capacitors and inductors. Corrections to the output voltage due to load or input changes are achieved by adjusting the pulse width of the high frequency waveform.

Sounds complicated? Yes, but the pay off is worth it!

**The advantages and drawbacks of both technologies**

**Size:** - A 50W linear power supply is typically 3 x 5 x 5.5”, whereas a 50W switch-mode can be as small as 3 x 5 x 1”. That’s a size reduction of 80%.

**Weight:** - A 50W linear weighs 4lbs, a corresponding switcher is 0.75lb. As the power level increases, so does the weight. I personally remember a two-man lift needed for a 1000W linear. Today I carry a 2000W in my carry on luggage when I fly!

**Input Voltage Range:** - A linear has a very limited input range requiring that the transformer taps be changed between different countries. Normally on the specification you will see 100/120/220/230/240VAC. This is because when input voltage drops more than 10%, the DC voltage to the shunt regulator drops too low & the power supply cannot deliver the required output voltage. At input voltages greater than 10%, too much voltage is delivered to the regulator resulting in over heating.

If a piece of equipment is tested in the US and shipped to Europe, or even to Mexico in some cases, the transformer “taps” have to be manually changed. Forget to set the taps? The power supply will most certainly blow the fuse, or may well be damaged.

Most switch-mode supplies will operate anywhere in the world (85 to 264VAC), from industrial areas in Japan to the outback of Australia without any adjustment.

The switch-mode supply will also be able to withstand small losses of AC power in the range of 10-20ms without affecting the outputs. A linear will not. No one will care if the AC goes missing for 1/100th of a second when charging your phone, it will take 100 of these interruptions to delay the charge by one second! Having a piece of equipment reboot 100 times a day will cause some heartbreak!
Efficiency: - A linear power supply because of its design will normally operate at around 60% efficiency for 24V outputs, whereas a switch-mode is normally 80% or more. Efficiency is a measure of how much energy the power supply wastes. This has to be removed with fans or heatsinks from the system.

For a 100W output linear, that waste would be 67W. A 100W switch-mode would be just 25W.

\[ 67W - 25W = 42W \] is the extra power lost

Doesn’t sound much, but don’t try touching a 40W light bulb! If the equipment were running 24 hours a day, then the extra losses would be 367kW hours, even at $0.1 per kW hour, that’s an extra $37 a year for a power supply that costs around $80.

As a quick note, in Europe, they are trying to limit those losses of all power supplies used by consumers particularly when operating off load (as many products are left plugged in 24 hours a day). Imagine 250 million power supplies eating up a couple Watts. That equates to the output of a whole power station!

Reliability: - If reliability is calculated using a part count method, then the linear power supply will win. With the design & quality improvements made in the last few years with switch-mode parts & technology, in reality this advantage has been negated. I have demonstrated life testing data showing no failures after over 1,000,000 hours on some Lambda products.

Electrical Ripple and Noise: - This is where the linear really scores!

The linear obviously is a lot “quieter”, by up to a 10,000 times. The topology of the switch-mode supply with its high frequency switching technology had to have a downside right? So if the noise is 10,000 times worse, how can anyone use it? Sounds so bad.

In truth, there are some applications (studio mixers and very sensitive test equipment) where low electrical noise is critical. The others? One of my first sales calls in the USA was to a manufacturer who built semiconductor fabrication equipment. They used 8 really big linear units in a large box measuring 2x3x4 feet, it was heavy & actually was dictating the size of their end equipment. I told the engineer that I could replace all eight units with two modular products measuring 5x5x10”. He laughed and said the noise would be too great. I sent him samples and went to visit three weeks later. He was delighted with the performance and has been a long term Lambda customer ever since.
Transient Response:

Transient response is how a power supply reacts to a (fast) change in load.

If the output load quickly changes from say full load to half load, the output voltage of the power supply will rise (overshoot) before the internal control circuit has time to compensate, and then undershoot a little less as the circuit over compensates. The length of time is takes from the instant of the load change to the time the output voltage settles back into the load regulation limits can be critical to some loads. Here the linear again outperforms the switch-mode.

For a 50% change in load the switch-mode will often take 3000us to recover. A linear supply will recover in 50us.

Is this critical for all applications? There are a few specialized technologies where this is important and most engineers will advise you if this is critical. For the other instances on board capacitors at the end load & the inductance of cables is enough to reduce overshoot down ten-fold to where it no longer is a concern.

Low leakage currents and Conducted EMI:

A widely used technique in the design of switch-mode power supplies is to connect special capacitors from the AC input terminals to Earth. This is an cost effective method to reduce noise from being fed back through the input wires and potentially affecting other equipment.

These capacitors have a side effect of allowing a “leakage current” to be passed through the Earth or ground cable. Many safety specifications have limits on the amount of this current that is allowed. UL1950 allows 3mA, medical industrials less than a tenth of that. The gaming industry is even tighter.

As linear power supplies are “quieter” and do not need these capacitors, they simplify the system filtering, and allow more of the system leakage current “budget” to be used for other parts like monitors. The overall size of the system filter can also be reduced. How much that impacts cost & performance varies from customer to customer.

Some switch-mode power supplies (like Lambda’s Vega series) are now available with increased internal filtering that allows for low leakage versions to be offered to meet medical specifications.

In Summary:

<table>
<thead>
<tr>
<th></th>
<th>Linear</th>
<th>Switch-mode</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>✗</td>
<td>✓</td>
<td>Typically 80% smaller</td>
</tr>
<tr>
<td>Weight</td>
<td>✗</td>
<td>✓</td>
<td>Typically 80% lighter</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>✗</td>
<td>✓</td>
<td>10% vs. up to 300% range</td>
</tr>
<tr>
<td>Efficiency</td>
<td>✗</td>
<td>✓</td>
<td>Calculate it long term!</td>
</tr>
<tr>
<td>Reliability</td>
<td>✓</td>
<td>✗ ✓</td>
<td>Component count method, demonstrated probably equal</td>
</tr>
<tr>
<td>Ripple &amp; Noise</td>
<td>✓</td>
<td>✗ ✓</td>
<td>Up to 10,000 times - often possible to overcome though</td>
</tr>
<tr>
<td>Transient Response</td>
<td>✓</td>
<td>✗</td>
<td>Up to 100 times - necessary in specialized areas</td>
</tr>
<tr>
<td>Low leakage Current</td>
<td>✓</td>
<td>✗ ✓</td>
<td>Often used in medical systems, switch-mode gaining share</td>
</tr>
</tbody>
</table>

As you can see, depending upon what is critical to the Customer will influence the decision to go with either a switch-mode or a linear power supply. It is often worth challenging the use of a linear. Sales of linear supplies (>10W) fall every year as technology adapts and improves.

I hope you found this article interesting and useful. If you have any questions or need further assistance, please call Lambda’s technical support. 1-800-LAMBDA-4.