POWER SUPPLY MEASUREMENT TECHNIQUES
Power Efficiency & Ripple Noise (TPS62120 vs. TPS7A4201)

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PREFACE

This publication has been assembled to assist in the development, testing, and comparison between two common power management solutions. The inspiration for this analysis comes from a design project which requires a portable, low power, solution to obtain a low-noise 5V supply from a 9V battery. After researching the semiconductor industry, two major power management solutions were found. The linear dropout regulator (LDO) and the switch-mode “buck” converter are two of the most common power supply solutions used when designing power management circuits. To make an objective decision for the design project, both circuit solutions were designed, built, and tested. The two integrated circuits used for comparison are the TPS7A4201 and the TPS62120. Both of these devices are manufactured by Texas Instruments (TI) and are a part of their current power management portfolio. The TPS7A4201 is a single linear dropout regulator and the TPS62120 is a switch “buck” converter with integrated FETs for the output stage. The function of both devices is to aide in the voltage regulation of a system’s power supply. When designing a power supply to reach a system level specification, there are many things to consider when choosing a power management solution. Noise, Stability, Voltage, are only some of the measurements that are commonly made when specifying a system’s power supply performance. In this publication, the measurement techniques of efficiency and noise will be addressed. Objective analysis and measurement is the best way for any engineer to compare two power solutions when designing for a specific application. The goal for this publication is to assist the reader in understanding the main differences between two power management integrated circuits as well as to gain an understanding as to how one can objectively measure and compare the noise levels and power efficiencies of these two types of devices.
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INTRODUCTION

When choosing between several power management solutions, system performance specifications need to be pre-defined and considered before a decision can be made about which solution will best meet the design criteria. Linear dropout regulators (LDO) and switch-mode “buck” converters vary in performance and as expected also vary in appropriate applications. The application covered in this publication is a power management solution for battery powered devices involving low voltage and low current levels. The TPS62120 (integrated switch converter) and TPS7A4201 (LDO) were selected, designed, and tested for the design project that inspired this analysis. The results and methods for testing will be discussed in detail to transfer the objective approach to the reader for re-use in system analysis and comparison.

The two circuit metrics under comparison between an LDO and a buck converter are the noise levels of the output as well as the power efficiencies of the devices. As a general pre-analysis discussion, it is generally understood that “buck” converters perform much better then LDO’s when it comes to power efficiency, however the noise levels emitted from the systems using buck converters are much higher than when comparing the levels of noise emitted from an LDO circuit.

Understanding these two metrics can help an engineer select between the two solutions when designing for a specific application. Buck converter power solutions are typically used for high power applications due to their high efficiency performance and LDO’s are often used to address minimal layout, low cost, and low noise solutions that can meet the system-level requirements for efficiency (battery life). The following metrics in Table 1 compare some of the datasheet specifications for the two devices. A quick comparison of the operating ranges of the two power management can be made. The table shows the specified maximum ranges of operating voltages and currents as well as other features highlighted for the devices.

<table>
<thead>
<tr>
<th></th>
<th>TPS7A4201</th>
<th>TPS62120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin (Min) (V)</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Vin (Max) (V)</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>Iout (Max) (A)</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Iq (Typ) (mA)</td>
<td>0.02</td>
<td>0.011</td>
</tr>
<tr>
<td>Pin/Package</td>
<td>8MSOP</td>
<td>8SOT-23</td>
</tr>
<tr>
<td>Vout (Min) (V)</td>
<td>1.161</td>
<td>1.2</td>
</tr>
<tr>
<td>Vout (Max) (V)</td>
<td>26</td>
<td>5.5</td>
</tr>
<tr>
<td>Noise (UVrms)</td>
<td>58</td>
<td>-</td>
</tr>
<tr>
<td>Price (US$)</td>
<td>0.28</td>
<td>0.75</td>
</tr>
<tr>
<td>Accuracy (%)</td>
<td>1</td>
<td>2.5</td>
</tr>
</tbody>
</table>
CALCULATING POWER EFFICIENCY

To calculate the performance of power supply systems, four metrics are needed to perform the analysis. The four metrics are listed as follows:

1. Input Voltage (V)
2. Input Current (A)
3. Output Voltage (V)
4. Output Current (A)

Once these four metrics have been obtained, the system input & output power can be calculated using Equation 1. For input power, input voltage and input current should be multiplied, and respectively, the output metrics should be used for the output power calculation.

\[
\text{Power (W)} = \text{Voltage (V)} \times \text{Current (A)} \quad (1)
\]

After the input power and output power of the system are measured and calculated, the power efficiency of the system can also be obtained using Equation 2.

\[
\text{Efficiency (\%)} = 100 \times \frac{\text{Output Power (W)}}{\text{Input Power (W)}} \quad (2)
\]

Linear regulators and buck converters that are used in step-down applications (i.e. 9V input to 5V output) will inherently have losses associated with the non-ideal effects of the circuitry used. These energy losses commonly exit power systems in the form of heat dissipation. This inherently manifests itself in consistent power efficiency measurements below 100%. Figure 1 shows a flow diagram of how the energy of a power management circuit can be broken down into parts for practically realizing the efficiency principle for all non-ideal systems.

![Figure 1: Non-ideal power loss leads to efficiency measurements less than 100%](image)

Calculating power efficiency is not difficult once the proper metrics are obtained. When doing power supply calculations, more focus should be placed on the measurement techniques used to obtain the individual metrics. Proper measuring techniques are very important to ensure reliable data is gathered.

MEASURING POWER EFFICIENCY

One of the most important variables when performing any electrical measurement is accuracy. The accuracy of a test is always limited by the accuracy of the instruments being used to make the measurement. Proper selections of the instruments and measurement techniques are both very important. For the purposes of power supply efficiency measurements, it is an appropriate technique to use a digital
A multi-meter (DMM) is used to measure the input and output voltage. If the digital multi-meter is capable of performing a shunt/series current measurement, this is also an appropriate technique for measuring the input and output current. If the DMM used can only measure voltage and does not have the circuitry required to measure current, then another common technique is to measure the voltage drop across a precise (tolerance < 1%) resistor with a value less than or equal to 1Ω. This resistor is often called a precision shunt resistor and allows for a precise measurement of current. This can be obtained by measuring the voltage drop across the shunt resistor calculating the current flowing through the resistor using Ohm’s Law in Figure 3.

\[ \text{Current (A)} = \frac{\text{Voltage (V)}}{\text{Shunt Resistance (Ω)}} \] (3)

The DMM used to perform the testing and measurements on the TPS7A4201 and the TPS62120 is the Fluke 8840A. This piece of equipment is a 5½ digit DMM capable of performing accurate voltage and current measurements. The Fluke 8840A is calibrated and specified to the following tolerances in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Current Measurement</th>
<th>Voltage Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>±0.005 %</td>
<td>±0.005 %</td>
</tr>
<tr>
<td>Resolution</td>
<td>10 μA</td>
<td>100 μV</td>
</tr>
</tbody>
</table>

**TEST SETUP**

The test setup for measuring the input and output voltage is shown in Figure 1. The test printed circuit board (PCB) contains both power management circuits to be tested. Appropriate test points were designed and placed at the input and output voltage terminals for the power supply and a DPDT switch was placed to quickly select and compare measurements between the two power circuits under test.

![Figure 3: Lab test setup used to measure the system input voltage](image)

As shown in Figure 4, header pins with jumpers were placed in series to shunt the input and output of the power circuit to allow for the series current measurements to be made. In the case of the board under test, good design and planning allows for easy access to make a variety of measurements. The white switch in Figure 4 is the DPDT that allows the device under test to be selected between the TPS7A4201 (LDO) and the TPS62120 (Buck Converter).
ANALYSIS OF RESULTS

After probing the test points to measure input and output voltage, and shunting the 2-pin header jumpers in series with the DMM to measure input and output current, the data in Table 3 summarizes the results of the measurements.

<table>
<thead>
<tr>
<th></th>
<th>TPS7A4201</th>
<th>TPS62120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage (V)</td>
<td>9.498</td>
<td>9.498</td>
</tr>
<tr>
<td>Input Current (mA)</td>
<td>0.74</td>
<td>0.43</td>
</tr>
<tr>
<td>Input Power (mW)</td>
<td>7.02852</td>
<td>4.08414</td>
</tr>
<tr>
<td>Output Voltage (V)</td>
<td>4.9306</td>
<td>5.1183</td>
</tr>
<tr>
<td>Output Current (mA)</td>
<td>0.67</td>
<td>0.71</td>
</tr>
<tr>
<td>Output Power (W)</td>
<td>3.303502</td>
<td>3.633993</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>47.00</td>
<td>88.98</td>
</tr>
</tbody>
</table>

The efficiency of the TPS7A4201 under the specified operating conditions is 47% while the TPS62120 is operating at 88.98% power efficiency. Linear dropout regulators become more efficient at lower voltage differentials, which makes them a perfect selection for applications requiring a minimal change in voltage from the input to the regulated output without undershooting the devices dropout voltage (i.e. 5V input to 3V output).

CONCLUSION

It is important to measure input and output voltage accurately in order to ensure a proper comparison between power devices efficiencies. The TPS62120 buck converter integrated circuit performs 42% more efficient than the TPS7A4201 linear dropout regulator.
DESIGN CONSIDERATIONS

Although switch-mode power supplies (TPS62120) operate at high power efficiencies, there are some drawbacks in their performance as well that can be valuable to note when choosing a power supply for a specific application. Figure 6 shows the functional block diagram of the TPS62120 taken from the datasheet. The main source of the noise emitted from the device comes from the input stage (right) where there are two PMOS and NMOS transistors.

Without proper signal conditioning, the noise generated from a switch-mode power supply can interfere with sensitive analog/digital circuits inside an electronic system. Another drawback to consider in a switch-mode power supply for your application is the larger board footprint. Many devices in today’s market have simplified the design process by integrating the power mosfets into the integrated circuit. Switch-mode power supplies often need more complicated external components (i.e. inductors, capacitors, resistors, diodes). Because of these external components, the layout space needed to place the circuit becomes inherently larger. The small size of the footprint and simplicity of the circuitry is one benefit to using a linear dropout regulator when comparing with a switch-mode power supply. Figure 7 shows the two reference schematics for the TPS7A4201 (top) and TPS62120. Note that the TPS62120 schematic requires more complicated external circuitry and layout considerations than the TPS7A4201. These are only limiting factors when an application requiring low noise and small size.
MEASURING POWER SUPPLY NOISE

There are many methods used for measuring power supply noise. Keep in mind that the method used for comparing the TPS7A4201 and TPS62120 output noise levels is just one of many. To perform the measurements, the Agilent 54833A Digital Storage Oscilloscope was used in conjunction with an Agilent 1161A 10:1 probe. After proper probe compensation, the scope was put in AC coupling and AC trigger mode to display and measure the amplitude of the noise present at the output voltage signal of each power device. The testing setup is shown below in Figure 8 with the oscilloscope displaying the switching noise at the output of the TPS62120 buck converter.

The input noise due to the switching PMOS and NMOS transistors on the input of the TPS62120 can be seen in Figure 9.

The switching noise spikes on the input are 26mV peak-to-peak in amplitude. The input noise from the TPS7A4201 is inherently smaller due to the operation of the device. Figure 10 shows the input noise from the linear dropout regulator circuit (TPS7A4201).

The input noise for the TPS7A4201 is measured at 6.7mV peak-to-peak amplitude. This ultimately leads to a
smaller output noise for the circuit as well. Figures 11 & 12 show the output noise for both circuits respectively.

![Image](image.png)

**Figure 11: Larger output ripple noise (TPS62120)**

The switch-mode power supply output noise signal shown in Figure 11 shows the voltage ripple that originates from the LC tank circuit at the output charging and discharging. The input and output noise levels for the LDO are under 10mV peak-to-peak and the output ripple voltage for the switch-mode power supply is measured at approximately 80mV peak-to-peak. Proper filtering and signal conditioning can be performed to remove and filter this noise to prevent interference, however this just adds to another drawback or consideration when choosing between different power supply configurations.

**CONCLUSION**

The efficiency and noise of the linear dropout regulator (TPS7A4201) and the buck regulator circuit (TPS62120) were performed. Both devices are manufactured and supported by Texas Instruments and as shown, both can be designed to perform very well in a variety of suitable applications. The TPS7A4201 has very low noise operation as well as a reliable adjustable output voltage level. The TPS62120 is capable of running at power efficiencies greater than 85%. Taking these strengths and weaknesses into account can allow any engineer to choose the correct device for a specific application. The measurement procedures for measuring efficiency and noise are not very difficult but it should be done correctly and accurately to aide in comparative analysis between devices.

**REFERENCES**

TPS62120 & TPS7A4201 Datasheets & Application Information www.ti.com