MEANS FOR MEASURING THE ELECTRIC AND MAGNETIC QUANTITIES

METHOD OF MEASURING PSRR FOR LINEAR VOLTAGE REGULATORS

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Abstract. The article describes a method for measuring the power supply rejection ratio and its characteristics. A simulation of the measurement in the LTspice program considering a linear voltage regulator as an example, with varying output capacitance is studied.

Key words: PSRR, power supply rejection ratio, linear voltage regulators, low dropout regulators, LTspice simulation program

1. Introduction

One of the items of any electronic device is chips that step down/up the voltage of the main power source for other circuit components. DC-DC converters are utilized for such conversion in mobile applications: smartphones, tablets, laptops, and other gadgets. The advantage of step-down mode is high efficiency compared to linear regulators. The disadvantages are the high electrical noise level, low signal accuracy, and the impact of load changes on the output voltage.

The increasing demand for renewable energy sources, energy storage technologies, and electric vehicles requires powerful DC converters [1]. These topologies have been developed considering higher efficiency, reliable control switching strategies, and failure-resistant configurations [2]. During the switching of internal transistors in DC-DC caused by transient processes, disturbances are introduced into the supply circuit through inductance coils in the form of electrical noise and output signal oscillations.

DC-DC negatively affects high-performance microchips. The power supply for image sensors in mobile cameras is susceptible to interference. In such or similar schemes, linear regulators are typically used. They are installed after DC-DC, where they can suppress oscillations with noise after the converter and stabilize the signal at the output.

There are two types of linear regulators: standard and low dropout (the minimum voltage required at the regulator to maintain regulation [3]). The difference between them lies in the pass element with the dropout value.

To ensure a stable power supply for image sensors in mobile devices, low dropout (LDO) linear regulators are specifically used. An operational amplifier is utilized to create feedback between the output and the internal reference voltage. This ensures the regulation of the signal, guaranteeing its stability.

2. Disadvantages

The main drawback in determining the power supply rejection ratio for a linear voltage regulator is the influence of other components of the circuit on the result. Capacitors, resistors, traces on the board, and conductors may introduce additional parasitic parameters that decrease the measurement accuracy.

3. Goal

The objective of this work is to develop a methodology for measuring the power supply rejection ratio for linear voltage regulators and determine the possibility of improving this parameter in electrical circuits.

4. PSRR Parameter in Electronic Circuits

The power supply rejection ratio (PSRR) is an indicator of how sensitive an electronic device (typically an operational amplifier) is to changes in the input voltage. This parameter is one of the main ones for LDO. Its value determines how well the device copes with the influence of noise or fluctuations in the input signal. It is a measure of output ripple compared to input ripple over a wide frequency range (from 10 Hz to 10 MHz is common) and is expressed in decibels [4].

The main advantages of linear regulators with high PSRR values are:

- Signal stability
- Less distortion
- Less sensitivity to power supply fluctuations

PSRR is important in devices where signal stability is critical. For example:

- Analog sensors that measure physical quantities such as temperature, brightness, etc., are sensitive to changes in input power.
- ADCs - reducing noise from the voltage reference source ensures more accurate conversion.
- Optical sensors for measuring or registering optical signals are mostly image sensors.

A high value of this parameter means that the device has a better ability to absorb input voltage fluctuations and noise.

Sometimes the PSRR value is insufficient for the productive operation of the circuit. Then the other methods need to be applied. One of them is incorporating a band-pass filter in the circuit to filter out frequency interference [5].

Measuring PSRR determines the value by which the output signal of the operational amplifier or other device changes relative to the change in the power supply voltage. This can be represented by the formula:

$$PSRR(dB) = 20 * log_{10}\left(\frac{V_{IN}\,rripple}{V_{OOUT_{rripple}}}\right) \qquad (1)$$

To determine this parameter, the oscillations of the output and input voltages are measured over a frequency range.

Fig.1 depicts a block diagram of a setup for measuring PSRR. This method is suitable only for LDOs with lower PSRR values due to the resolution and sensitivity limitations of the oscilloscope [6]. The problem with using a regular oscilloscope is that the output signal may be in the range of a few millivolts and cannot sometimes be measured accurately. To measure the input or output signals more accurately, a spectrum analyzer is applied, or specialized oscilloscopes that can build a Bode plot directly. With the mentioned devices, measuring the control loop response and the rejection ratio of power supply impulses, various means can be characterized, including passive filters and amplifier circuits [7].

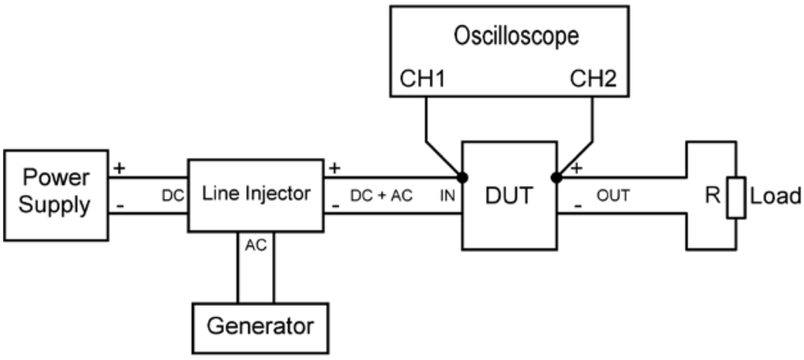

Fig. 1: Block diagram of the PSRR measurement setup

The PSRR measurement setup should disable an input capacitor. It is absent for evaluation due to the built-in ability to suppress input noise [8]. However, the chip begins to generate oscillations due to feedback. Therefore, the manufacturer may indicate in the documentation the necessity of using an input capacitor.

To measure input and output oscillations for determining PSRR, the following equipment is utilized:

- Chip being tested for the PSRR parameter, also known as the Device Under Test (DUT)
- Power supply for the input voltage of the microchip (DC component)
- Generator for generating an AC signal
- Device for mixing DC and AC signals, which is connected to the DUT input, which is also known as Line Injector
- Oscilloscope for measuring the signal amplitude at the input and output of the DUT
- Load, which is connected to the output of the chip. For example, a resistor, which does not introduce parasitic parameters into the circuit.

The signal mixing device is used to create a sinusoidal waveform at a certain voltage level. During the measurement of input/output oscillations in the frequency range, any additional inductance affects the measurement result. So, the connected conductors should be as short and as uniform in length as possible. Also, is important to calibrate the equipment considering these factors to eliminate the influence of parasitic parameters while measuring.

1. PSRR measurement simulation example with LTspice software

In LTspice XVII, each component is represented by a common mathematical model. Such presentation is based on an equivalent circuit consisting of resistors, capacitors, inductors, and sources. Each basic component is characterized by one or several numerical values that precisely define its behavior [9]. Due to its high speed and accurate results, the simulator is popular in its class.

The LT3042 is a high-performance low-dropout linear regulator with ultra-low noise and exceptionally high PSRR architecture for powering noise-sensitive radio frequency devices [10].

Fig. 2 shows the schematic for simulating PSRR measurement in LTspice. The input voltage of the microchip is 5 V, with an added variable component with an amplitude of 1 V. The output voltage is set using resistor R5 and is equal to 3.32 V. A 4.7 μF capacitor is placed at the output. The load is regulated by resistor R6 and is set to 200 mA.

Fig. 3 shows the input and output signals of the linear voltage regulator microchip at a frequency of 1 MHz. In this image, the difference in amplitude can be observed, indicating the suppression of input oscillations. According to formula (1), the PSRR value is calculated for a frequency of 1 MHz:

$$PSRR(dB) = 20 * lg_{10}\left(\frac{V_{IN_{rripple}}}{V_{OOUT_{rripple}}}\right) = 20 * lg_{10}\left(\frac{V_{IN_{max}}-V_{IN_{min}}}{V_{OOUT_{max}}-V_{OOUT_{min}}}\right) = 20 * lg_{10}\left(\frac{5.4996-4.5005}{3.3201-3.3199}\right) = 75\ dB \quad (2)$$

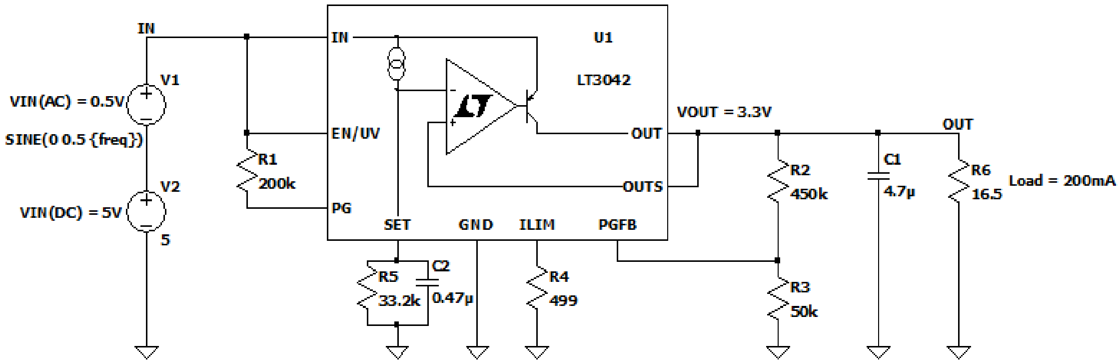

Fig. 2: Schematic of LT3042 for simulation in the LTspice program

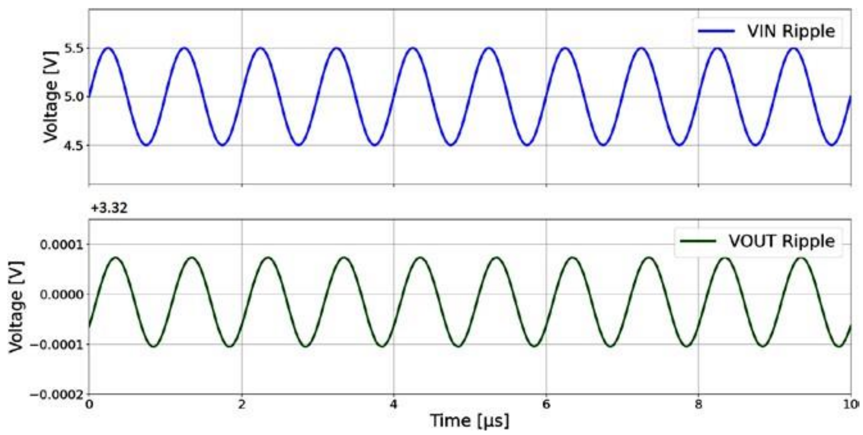

Fig. 3: Simulation of input and output voltages of LT3042 using LTspice

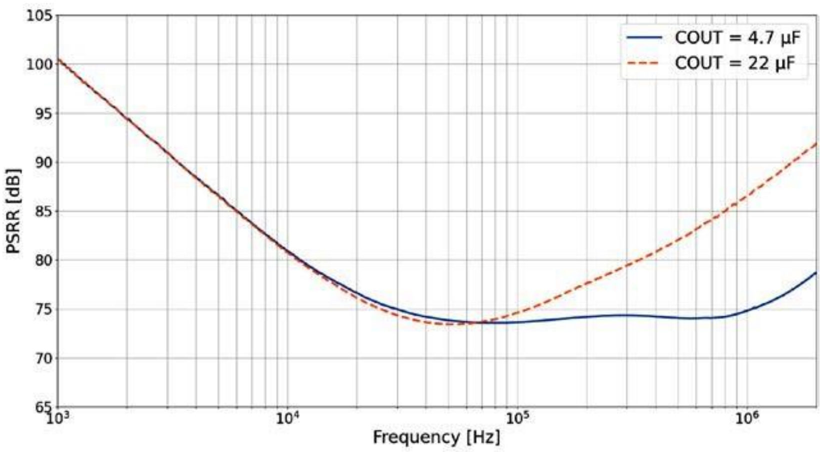

Fig. 4: Simulation of PSRR measurement in the LTspice program

The result obtained through simulation is close to the specified value in the documentation; the difference between the specified and simulated values is 4 dB.

In the frequency range from 1 kHz to 2 MHz, a PSRR calculation graph was obtained by simulation in the LTspice program (Fig.4). Discrepancies in the simulation results were identified for output capacitors of 4.7 μF and 22 μF. From the graph in Fig.4 (orange line), it can be seen that the PSRR was improved due to the increased capaci- tance at the output of the microchip.

Microchip manufacturers specify the effective value of capacitors. The capacitance changes with temper- ature or changes in the frequencies at which it is utilized. Therefore, components should be selected considering the capacitance changes.

2. Conclusions

The method for determining the power supply rejec- tion ratio by measuring input and output voltage deviations was developed. Within the LTspice program, the LT3042 (high-performance low dropout linear regulator featuring LTC's ultralow noise and ultrahigh PSRR architecture for powering noise-sensitive RF applications) was simulated with different output capacitors. It has been found that the PSRR can be improved by increasing the capacitance. The impact of the capacitor was particularly noticeable at fre- quencies above 100 kHz.

3. Conflict of Interest

The authors declare the absence of any financial or other potential conflict related to the work.

4. Gratitude

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