Power Supply Noise Effect Module

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CONCEPT OF OPERATIONS

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Concept of Operations
for
Power Supply Noise Effect Module

Team 49

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1. Executive Summary

Regulating DC voltages is crucial in PCB design, with switching regulators being a common method. These regulators work by switching on and off to regulate the voltage to a desired level. While effective, switching regulators can introduce ripple and noise, which may interfere with sensitive circuits. To address these issues, Linear Dropout Regulators (LDOs) are often used as an alternative. LDOs are highly efficient at regulating DC voltages with a minimal difference between the input and output voltages. Unlike switching regulators, LDOs do not generate ripple or noise, making them ideal for clean power delivery.

The goal of this project is to showcase the effectiveness of LDOs in maintaining a clean power rail compared to other power delivery methods, such as switching regulators and bench power supplies. The project will involve designing a primary PCB that integrates three methods of power delivery: an LDO (specifically the TPS79A4 from Texas Instruments), a switching regulator, and a bench power supply. These power rails will be selectable via control relays, managed by an MSP430 microcontroller.

A Digital-to-Analog Converter (DAC) will be used to evaluate the impact of these different power rails on the output signal. The DAC’s output will be displayed on an oscilloscope for a detailed analysis of how each power delivery method affects signal integrity.

To add remote functionality, a secondary PCB with an ESP32 module will act as an intermediary between the primary PCB and a mobile app. The app will display the DAC output in real time and allow users to remotely switch between the different power rails by sending commands to the ESP32, which will then relay the instructions to the MSP430. This setup will demonstrate how various power delivery methods influence the DAC output and signal quality, all controlled and monitored via the app.

2. Introduction

Digital analog converters (DACs) are devices that have their output voltage tied to the clarity of the attached power supply. A low dropout regulator (LDO) is a linear regulator that outputs a steady voltage from a varying input voltage, with an ultra-low noise LDO having noise values around 1 μV_{rms}, such as the ADM7154 with a value of 0.9 μV_{rms} [1] or the RAA214020 with a value of 6.3 μV_{rms} [2]. Attempting to limit the noise on the output of a DAC has motivated the creation of a Power Supply Noise Effect Module, which takes several different power supply inputs and tests their effect on the output of a chosen DAC. This module will be able to demonstrate the effectiveness of an LDO in reducing DAC output noise which will in turn influence consumers to choose LDOs when relying on precise DAC output.

2.1. Background

This module's main goal is to look at an LDO produced by TI and show the improvement in signal quality over other types of power supplies when used with a high-speed DAC. DACs can be powered in various ways but are typically powered by either a high-efficiency switching regulator or a less efficient and less noisy linear regulator. Implementing a boot resistor, snubber circuit, or ferrite beads into a switching regulator can reduce the noise [3], however, this requires more design time. Using an ultra-low noise LDO skips this requirement and instead outputs a low noise voltage, to begin with. This is suitable for applications using a DAC as a DAC output is reliant upon a consistent power supply input to produce a clear and fairly noiseless signal. Ultimately the usage of an LDO would be beneficial for high-speed DACs and this module's goal is to be a portable way to show the decrease in noise while using an LDO.

2.2. Overview

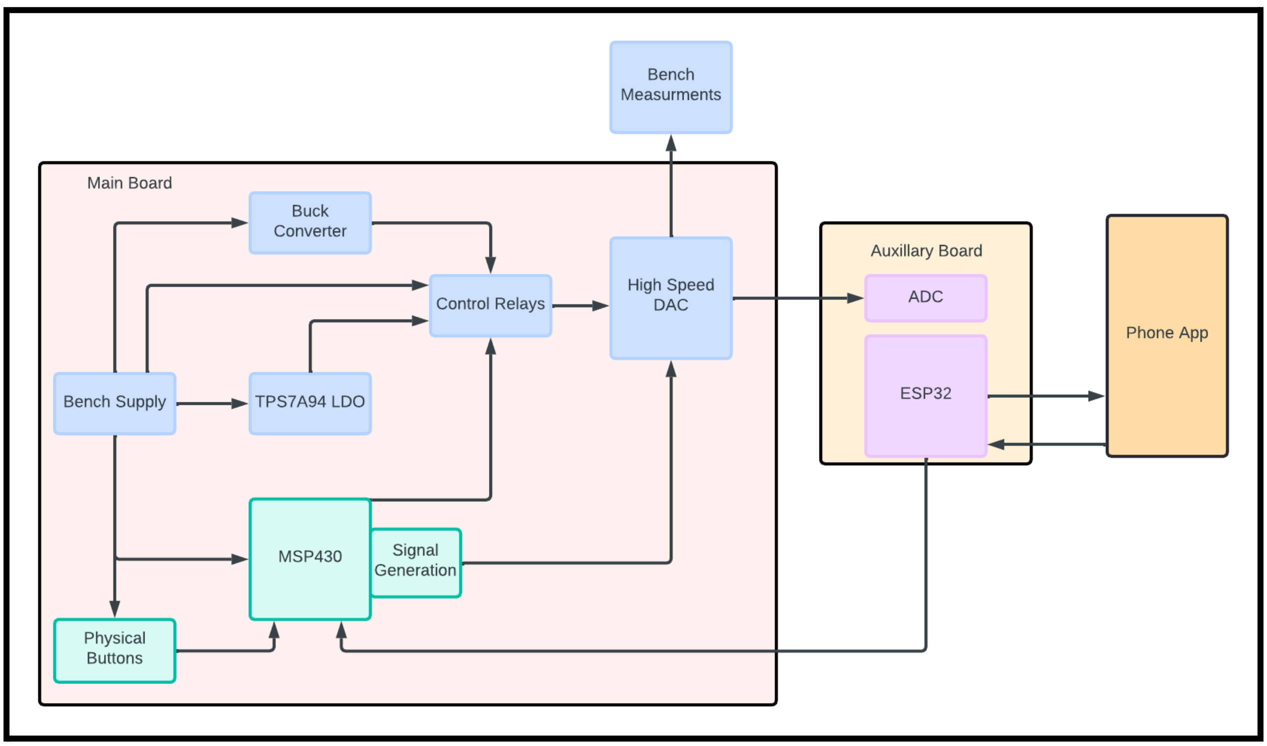

Figure 2.1 Noise Effect Module Block Diagram

The module is made of two main components, the Main board and the Auxiliary Board. The main board is composed of three power rails, one connected to a bench supply, one to a switching (buck) regulator, and the last to the TPS7A94 LDO. The MSP430 controls which of the three power rails is connected to the DAC through physical buttons. The MCU also generates a chosen digital signal to send through the DAC which can be viewed through an attached scope. The auxiliary board is meant to supplement the main board by providing a way to control and view data from a phone app. The analog data from the DAC is fed back into an ADC such that the signal can be transmitted to the connected phone over Bluetooth via the ESP32. The phone app can view the signal output as well as change which rail is active. Switching rails should show differing levels of noise among the three different power supplies.

2.3. Referenced Documents and Standards

[1] Analog Devices, “600 mA, Ultralow Noise, High PSRR, RF Linear Regulator”, ADM7154 datasheet, Oct. 2014

[2] Renesas, “Ultra Low Noise, High PSRR, LDO”, RAA214020 datasheet, June 2021 [Revised Dec. 2021]

[3] D. Hubbard, “Reducing noise on the output of a switching regulator” in *Analog Design Journal*, 3Q 2017. [Online] https://www.ti.com/lit/an/slyt740/slyt740.pdf?ts=1725993141743&ref_url=https%253A%252F%252Fwww.google.com%252F

This project will use IEEE 802.11b/g/n for Wi-Fi communication.

This project will use a Serial Peripheral Interface (SPI) for onboard communication. Devices used will fall under the Bluetooth V4.2 BR/EDR and Bluetooth LE specification.

3. Operating Concept

3.1. Scope

The power supply noise effect module will showcase the difference in noise output from using a TPS79A4 LDO in comparison to using a direct power source or switching regulator. This will be done through the input of a basic waveform using different power supply input to compare the differences in noise at the output. The module will be able to be controlled manually but will have an associated application for an alternative method of control and as a way to view the results.

3.2. Operational Description and Constraints

The power supply noise effect module will be used to outline the differences in noise from using a TPS79A4 LDO and other more direct power sources. A waveform will be generated and input into a DAC, which is powered either directly, with a switching regulator, or with a TPS79A4. The waveform is then measured for noise comparison between power inputs. The primary purpose of this module is an advertisement for the provided TI LDO.
The module must meet the following constraints:

- The LDO used must be the provided TPS79A4.
- The module must be portable for customer demos.
- The MCU must be able to be manually controlled without the use of a separate app.
- The module must have some method of displaying results. An oscilloscope is acceptable if the module is functioning without the auxiliary board or associated app.

3.3. System Description

- MCU and Signal Generation: The MCU will send control signals to the control relays, power rails, the DAC, and the signal generation. The signal generation will create a simple, measurable signal to send to the DAC to be measured at the output.
- Power Rails and DAC: This subsystem will provide power to the DAC from different control relays, one of which will come from the provided TPS79A4 LDO, and another will be from a switching regulator. The DAC will take input from the signal generation and send data for noise measurement.
- Auxiliary Control Board: This subsystem will send and receive data to and from the control and visualization app to view the signal results and to be able to send control signals to the MCU.
- Real-Time Control and Data Visualization App: This subsystem will take data from the auxiliary board. This data will be visualized in real-time. The subsystem will also send control inputs to the auxiliary board.

3.4. Modes of Operations

The noise effect module will have three modes of operation in terms of the power input to the DAC.

- LDO Input: The DAC will be powered by the TPS79A4 LDO.
- Voltage Regulator Input: The DAC will be powered by the power supply directly through a buck converter.
- Power supply input: the power supply will power the DAC directly, after stepping down the voltage.

The noise module will have two different modes of operation in terms of control input:

- Real-Time Control and Data Visualization App: The module will be controlled remotely through the app through the auxiliary control board. Results will be able to be viewed remotely through the app.
- Manual Operation: The module will function without connecting to the auxiliary control board or the associated control and visualization app. Control will be done through the use of physical switches to choose between the different power rails at the control relays,

3.5. Users

The primary users of this system will be TI employees demoing their LDO for advertisement and data collection. The intent is to demonstrate the noise reduction to be gained from using the TPS79A4 LDO.
Controlling the board directly will require minimal training, however, the individual using it must be able to connect the board to a power supply and set the voltage manually, as directed. They must also be able to measure waveforms using an oscilloscope.
If the module is being controlled through an app. This will require less training to measure the waveform, but the user must install the app, connect to the board through Bluetooth, and control the board through the app. Using the app will require minimal training, however, it will require basic knowledge of waveforms to understand the results.

3.6. Support

A user manual will be provided. This manual will instruct how to connect the power supply to the module and what voltage the supply should be. This manual will additionally have instructions detailing how to connect an auxiliary oscilloscope for measurement. Beyond this, the manual will detail how to control the module both manually and give detailed instructions on app installation and use. The app itself will have further instructions with a help section to instruct users how to control the module remotely and view results.

4. Scenarios

4.1. Customer Demonstrations

One use case for the project is in customer demonstrations. The board can be used to showcase the effectiveness of Low Dropout Regulators (LDOs) in high-sensitivity applications. By directly comparing LDOs with other power sources, the board will illustrate how LDOs maintain cleaner, noise-free voltage rails, making them ideal for precision circuits. This hands-on demonstration will provide customers with a clear understanding of the benefits of LDOs in their designs, particularly in scenarios where noise and ripple are critical concerns.

4.2. Data Collection and Research

Another use case involves data collection and research. Currently, there is limited information available on how different power sources affect the output of DACs, especially regarding noise. This board offers a way for quantifying those effects. Texas Instruments could use this data to gain insights into the impact of power source noise on DAC performance, enabling better product development and refinement. The collected data could also serve as a resource for future research and provide valuable information for optimizing power delivery in noise-sensitive applications.

5. Analysis

5.1. Summary of Proposed Improvements

- The system will be a self-contained testing unit to display how effective different methods of noise reduction are.
- The system will be able to test all scenarios within the same setup.
- The system will have real-time data visualization accessible from a mobile app or oscilloscope.
- The system will use Bluetooth technology to communicate with a mobile device that will have selection over the control inputs of the system.

5.2. Disadvantages and Limitations

- The high-speed DAC used may have a higher impact on filtering noise than desired, potentially masking the ineffectiveness of some regulators.
- The mobile app’s real-time data visualization may have visual latency that will not synchronize with the oscilloscope.
- The latency from the Bluetooth may be a disadvantage as to using manual switches to control the regulators.

5.3. Alternatives

- The LDO could be tested in a much simpler system design that may effectively demonstrate its noise-filtering capabilities.
- However, such an alternative may be more manually involved and less neatly displayed in an all-in-one system.

5.4. Impact

- An ethical concern will be representing the product fairly in comparison to the other tests without distorting results in favor of the sponsor.