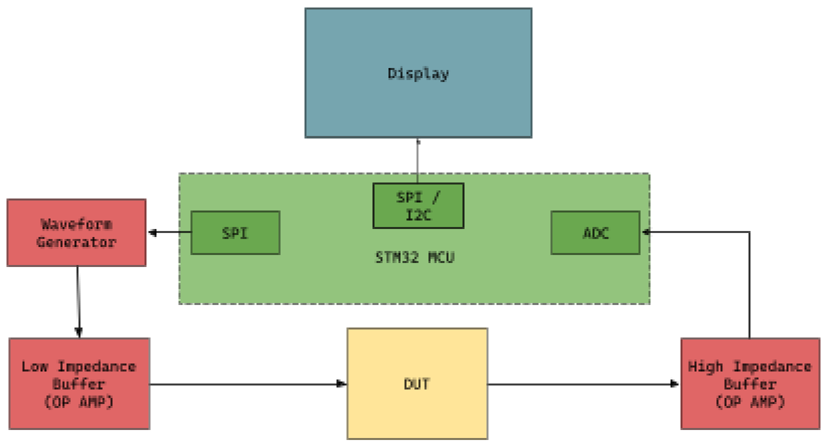
Audio Device Spectrum Tester

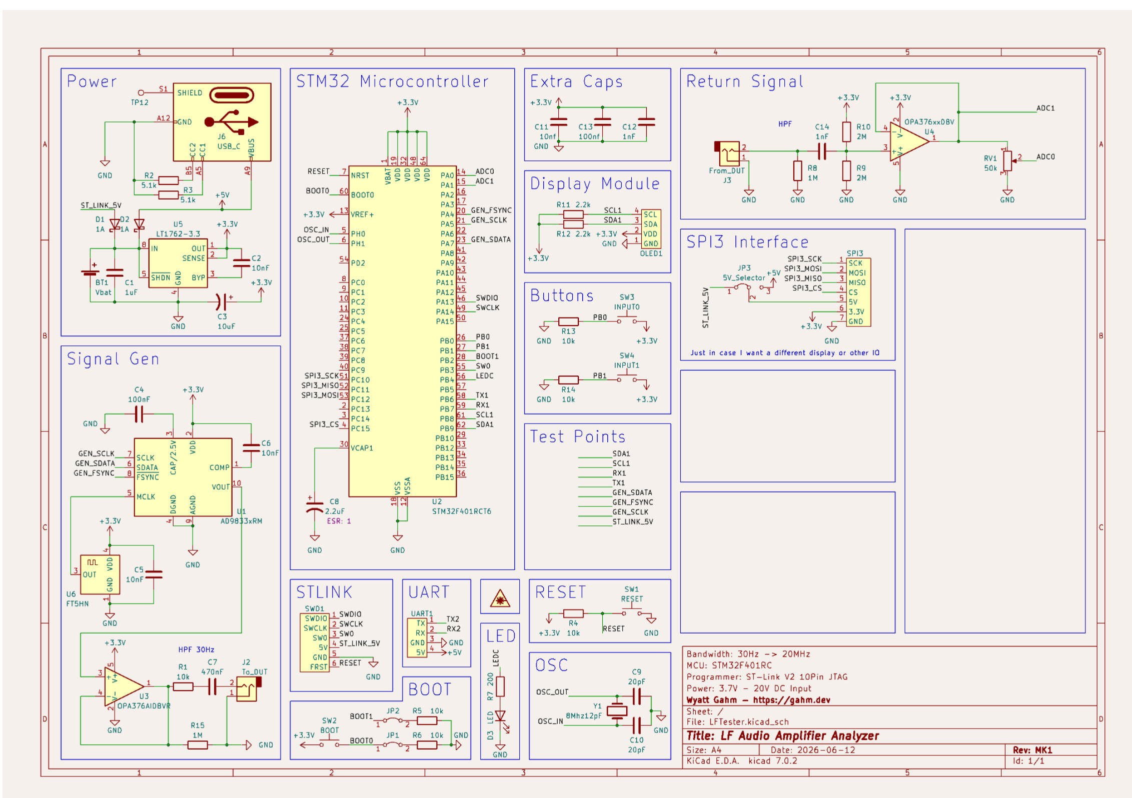
Embedded Low Frequency Measurement Device

Background

When designing audio equipment like amplifiers and effect pedals, it is useful to be able to map the magnitude response to the audible band of frequencies. It is also useful to measure any harmonics or noise that these amplifiers introduce. A portable device is desired which has appropriate input and output impedances such that “unity gain” devices can be verified, or even to test simple RC circuits.

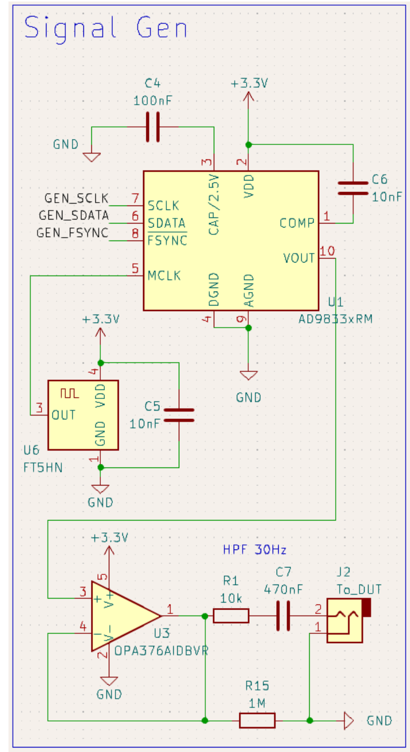
The intended use is for testing pedals or DIY amplifiers, so the frequency characteristics are tuned to replicate the behaviour of guitar and amp situations.





Generating A Waveform

The easiest way to generate a clean sine wave is to use a sine table and a DAC. STM32 microcontrollers are typically clocked around 48MHz and only the top of the line models include a DAC. Some googling pointed me towards the Analog Devices AD9833 Waveform generator, which can be controlled to output a variety of wave types without needing complex DAC and DMA configurations. Basically someone already thought this one out and made a basic IC that can output 0-12Mhz.



Outputting

In order to actually output to the device-under-test, I buffer the output with a unity gain non inverting configuration. The AD9833 has an output ranging from 650mV to 50mV, which TI's OPA376 series SOT-23 Op Amps are able to handle (rail to rail within 20mV, 2V/s slew rate, low noise, etc). The output circuit is designed to be shorted or to be able to sink power, but mainly to mimic the signal coming from a device like a Humbucker guitar pickup in impedance and voltage.

All signal connections are terminated with 2.5mm jacks.

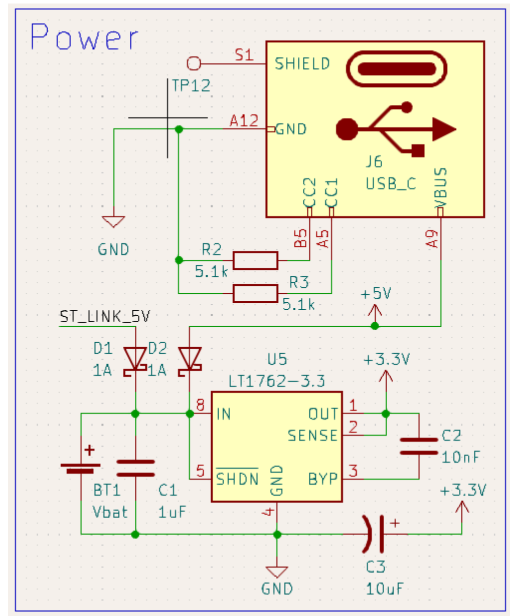
Power Design

The main system is fed with a low noise, low dropout LDO (LT1762) at 3.3 volts.

Device	Min	Typ	Max
STM32	6.1 mA	14.4 mA	20 mA
OPA376	500 uA	760 uA	30 mA
AD9833	-	4.5 mA	5.5 mA
FT5HN	-	6 mA	-

All in all, the 150mA power budget should accommodate the devices in normal operation.

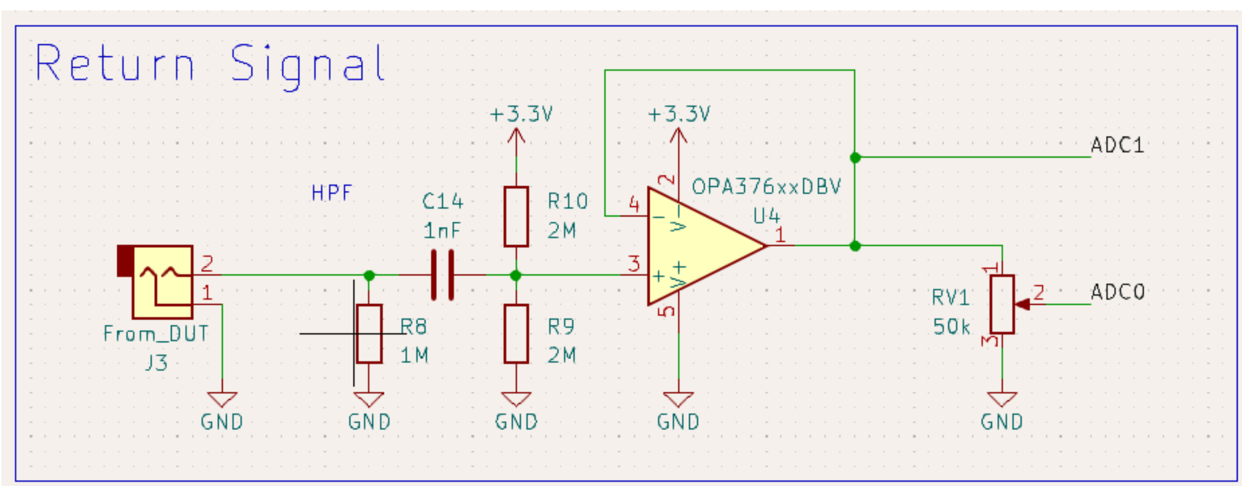
Upstream, the power is sourced from a USB-C 5V power supply OR a 3.7V battery. With the maximum voltage headroom supported by the LDO (20V), the device would have to dissipate 3W of power, which is low enough to eliminate the need for a noisy DC-DC converter.



The 5V voltage inputs are protected from each other by a diode setup, so that the ST-LINK and USB-C can be used simultaneously. The battery, however, should not be connected when operating in these modes (intended for use when the system is fully mobile).

Return Signal

The signal coming back from the DUT is processed with a high impedance configuration similar to the input for an amp or a next effect pedal in the chain. A potentiometer is used to load the op amp output and connect to the ADC, as well as using another ADC channel to bypass just in case.

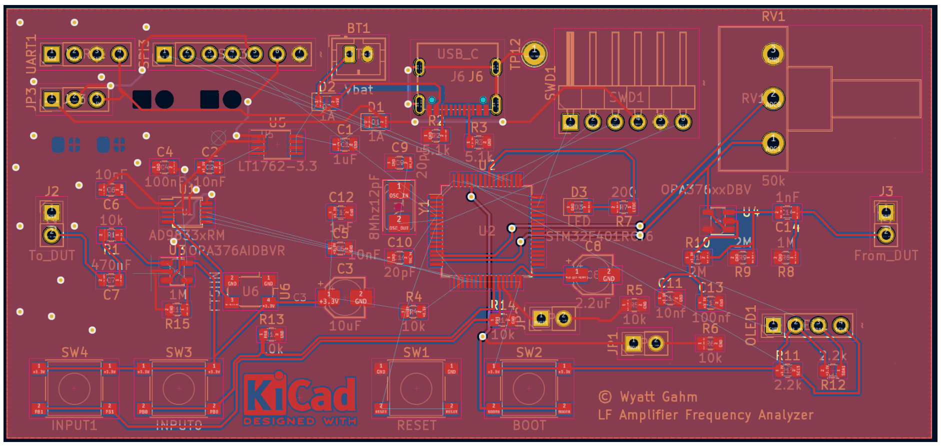


Flexibility

Additional IO ports are exposed for the use of different

Manufacturing

As I lack some of the equipment needed for a good SMD soldering setup, I designed the system to be ordered and assembled by JLCPCB. They have great coupons BTW. Every component is available through the supplier LCSC, and a python script (I didn't make it) is used to generate a pick and place file. The PCB will look something like this.



I have to reroute it before I can order it, including more tests with crosstalk and 3.3V bus stability. All the components are selected based on capability, and then supply chain support for lead time and highest stock (and then lowest cost)

Expect part 2 when everything arrives. I expect to test the configuration with a variety of simple single op amp effects (maybe a few BJTs in the config), plus a BOSS DS-10 pedal.

Software Design

The STM32F401 processor was selected for the ARM Cortex M4 feature set. The onboard FPU and SIMD support allows for efficient computation of FFT. The DMA controller is to be used to output a graphics buffer to the display in addition to transferring ADC data to memory.

The core modes of the devices are as follows:

- Bode plot
  - Magnitude plots over the audible spectrum
- Oscilloscope
  - Plot signal at a single freq for analyzing clipping and other distortions
  - Measure peak voltages and frequencies of any input signals
- Harmonic Analysis

    - Use an FFT to measure the relative strengths of the overtones and noise

Transient analysis is not easily possible with the setup, only AC steady state measurements.