# RF Payload for FM Signal Mapping in Low Earth Orbit

Titu Samson

## 1. INTRODUCTION

This payload is designed for a 3u cubesat to detect and measure and map FM signal strength in the low earth orbit. Noise power estimation, block diagram and circuit diagram of different blocks are explained in this document.

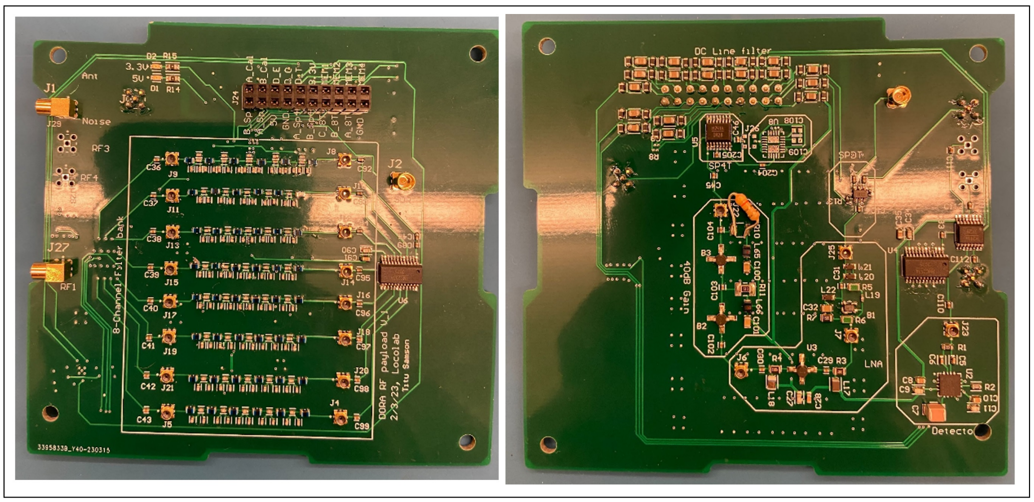


**Fig. 1.** RF payload PCB top and bottom

RF payload is a double-sided PCB with a series of switches, gain blocks, bandpass filters, and detectors. Figure 1 shows the top and bottom sides of the DORA RF payload.

## 2. NOISE POWER ESTIMATION

CubeSat antenna picks up signals from many sources in orbit, including galactic and Earth noise temperatures. The thermal radiation emitted by the atmosphere, surface, and other terrestrial objects is referred to as the Earth's noise temperature. It is a background noise that interferes with radio frequency applications such as communication systems. Depending on elements like the operation frequency and the satellite's precise position, the Earth's noise temperature can change. The Earth's noise temperature at microwave frequencies is typically several hundred to a few thousand Kelvin. Galactic noise temperature, on the other hand, is the thermal radiation emitted by celestial sources within the Milky Way galaxy. It includes emissions from stars, interstellar gas, dust, and other astrophysical phenomena. The galactic noise temperature varies with frequency, and its value depends on factors such as the location of the observer, the line-of-sight path through the galaxy, and the presence of local interference sources. The galactic noise temperature can range from a few Kelvin to tens or hundreds of Kelvin at microwave frequencies. For the calculation purpose earth's noise temperature is assumed as 300K and 1000K for galactic noise.

The expected input noise power at the antenna is calculated as

Pn=kTnB(watts/Hz)

B= band width in Hz

Earth noise temperature is 300 K Earth Noise power =-173.82dBm/Hz Integrated noise power over 20MHz bandwidth = -100.8177dBm/20MHz Galactic noise at 1000K Galactic noise power =-168.5992dBm/Hz Integrated Galactic noise power over 20 MHz =-95.5889dBm/20MHz

The average noise power at the input of the antenna will be around -95dBm A series of gain blocks have to be added after the antenna to put the noise level within the detectable range of the

RF power detector. In this system, a total RF path gain of around 68 dB is added before the 20 MHz filtering.

## 3. BLOCK DIAGRAM

In the block diagram, the noise signal from the antenna is first connected to a Low-Noise Amplifier (LNA) through an SP2T switch. The second port of the SP2T switch is connected to a broadband noise source, which is used for system calibration. This noise source provides a signal that remains constant over time, facilitating accurate calibration. The LNA provides a gain of 28 dB, amplifying the received noise signal. The amplified signal then passes through a gain block, which further increases the signal power by 40 dB. The output of the gain block is connected to an SP4T switch. The SP4T switch has four ports. One port is connected to a filter bank, another port is connected to a Software-Defined Radio (SDR), and the third port is connected to a MEMS switch. The fourth port of the SP4T switch is left open. The MEMS switch is an SP4T switch used to test its performance in the space environment. The four input ports of the MEMS switch are tied together and connected to the SP4T switch, while the output of the MEMS switch is connected to the SDR. To implement an eight-channel 20 MHz bandpass filter bank, two SP8T switches and eight 20 MHz bandpass filters are used. The output of the filter bank is connected to a calibration switch, which is an SP4T switch. For system calibration, a Keysight FieldFox spectrum analyzer is used as the standard and connected to one port of the SP4T calibration switch. Another port is connected to an optional standard RF power meter, and the third output is connected to the log detector in the system. This block diagram represents a complex system for noise signal processing and calibration. The various switches, amplifiers, filters, and measurement instruments work together to ensure accurate and controlled signal processing in the specified frequency bands.

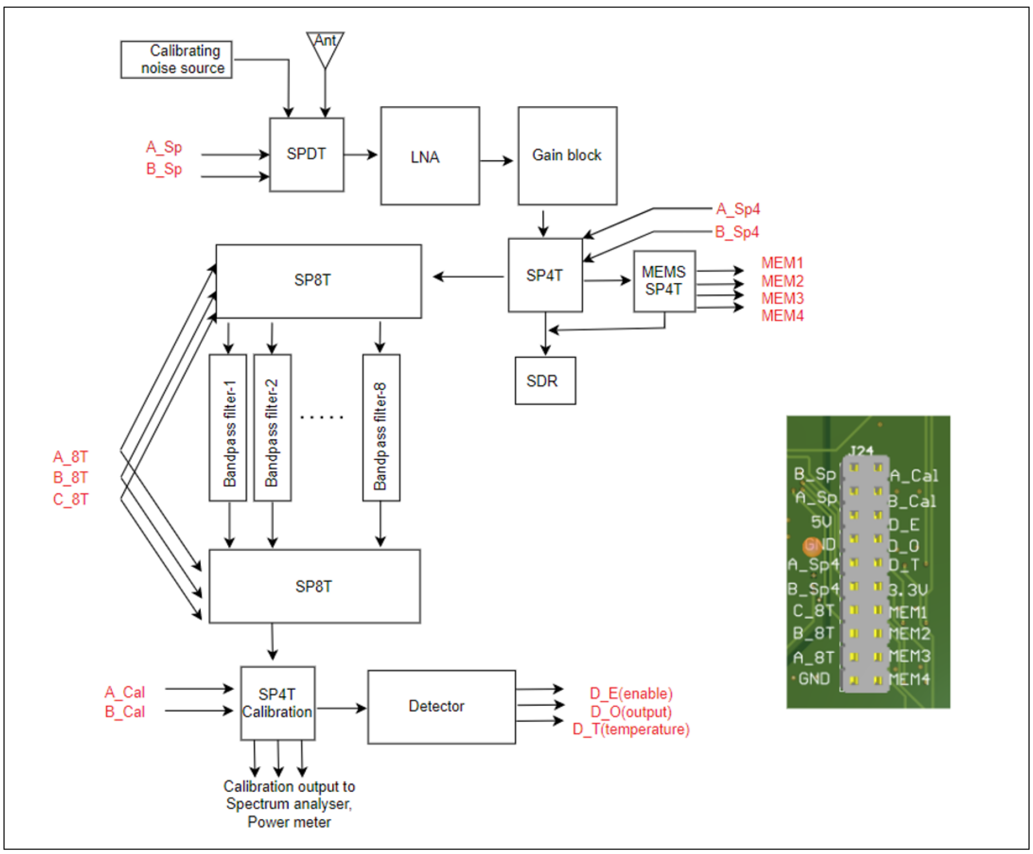


**Fig. 2.** RF payload Block diagram

## A. Schematic of each RF blocks

### *A.1. SPDT*

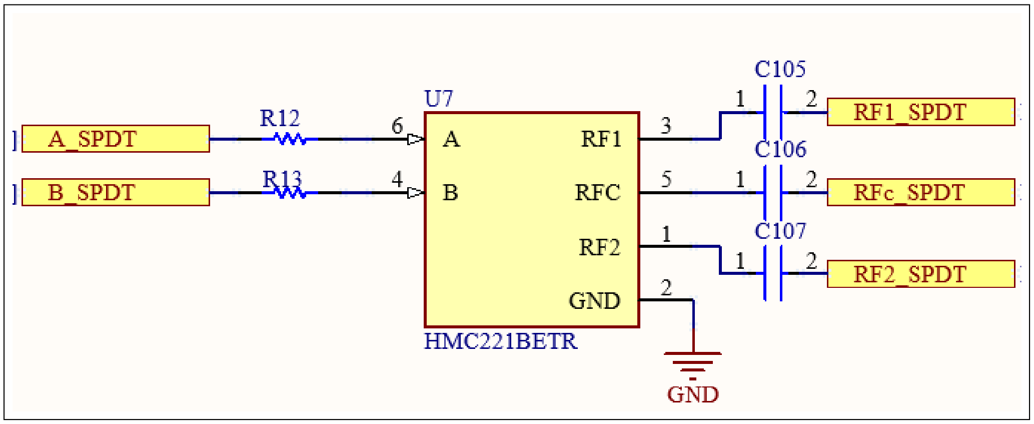


**Fig. 3.** Low noise amplifier

### *A.2. LNA*

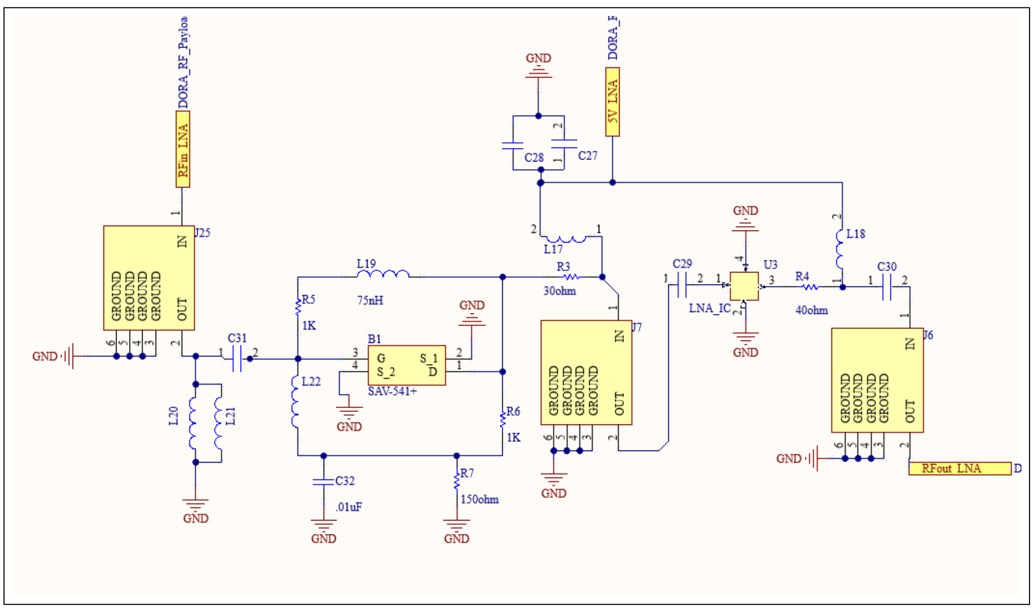


**Fig. 4.** Low noise amplifier

### *A.3. 40dB Gain block*

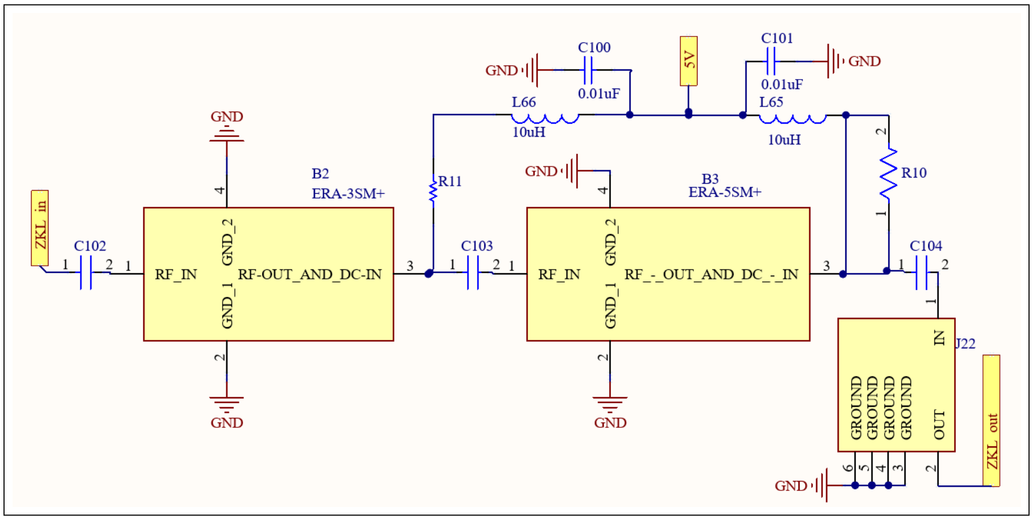


**Fig. 5.** 40dB gain block

### *A.4. SP4T*

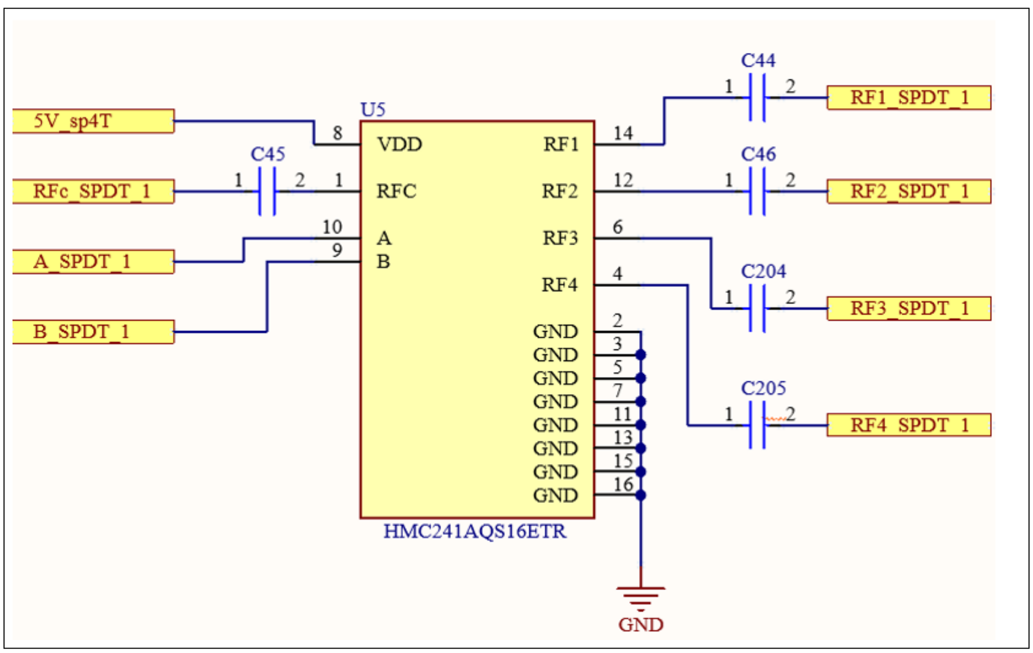


**Fig. 6.** SP4T RF switch

*A.5. SP8T*

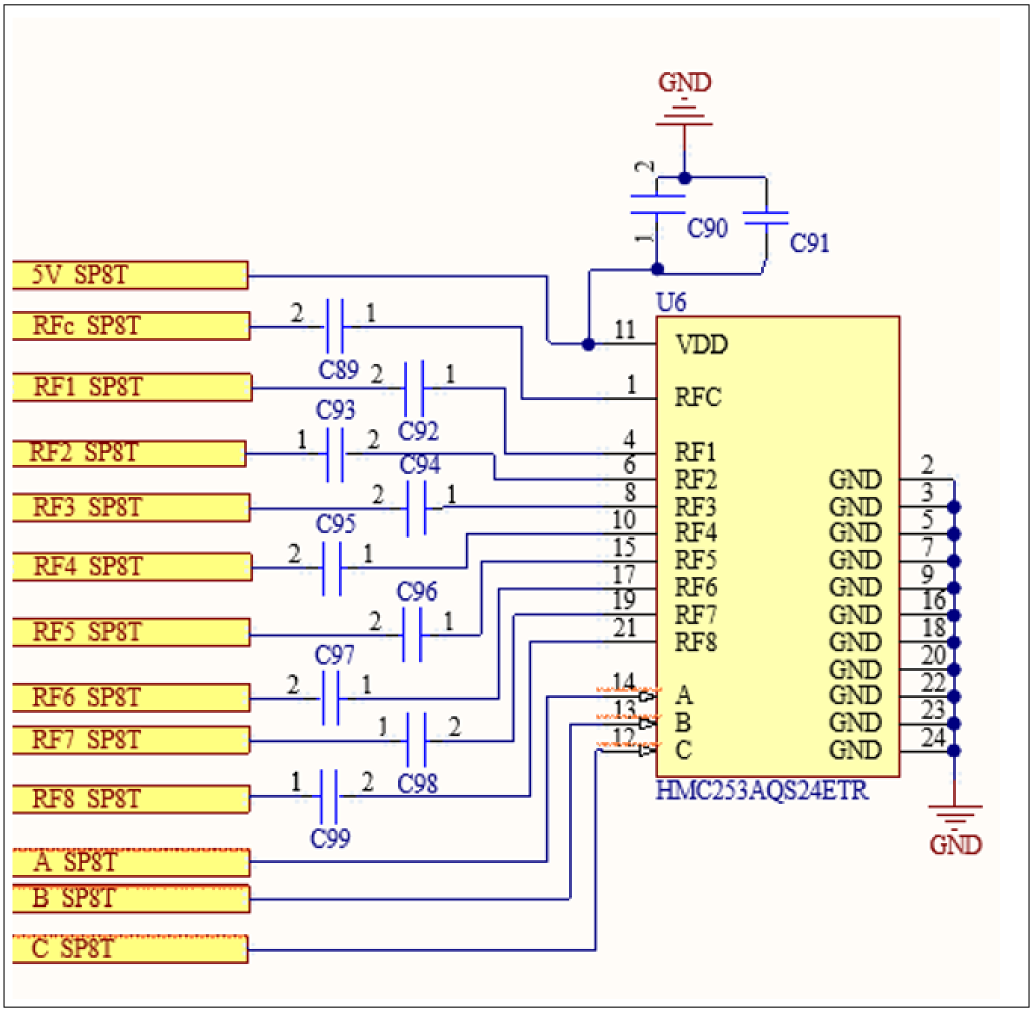


**Fig. 7.** SP8T RF switch

*A.6. Band pass filter bank*

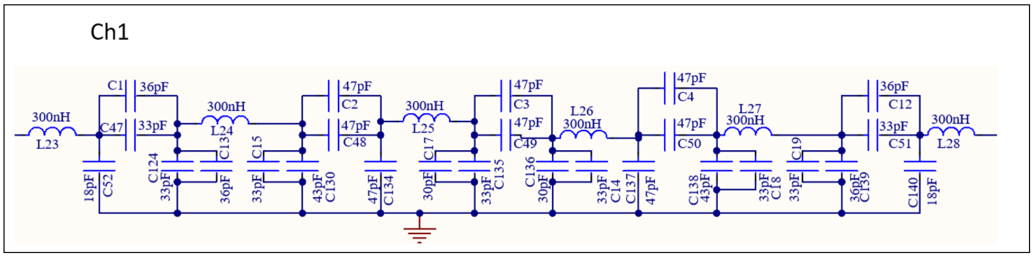


**Fig. 8.** Band pass filter channel 1

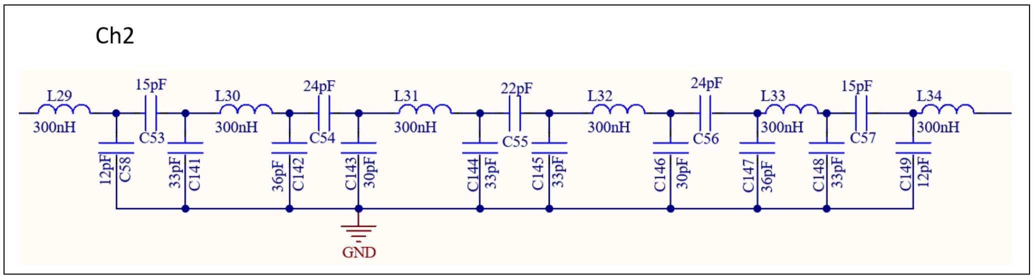


**Fig. 9.** Band pass filter channel 2

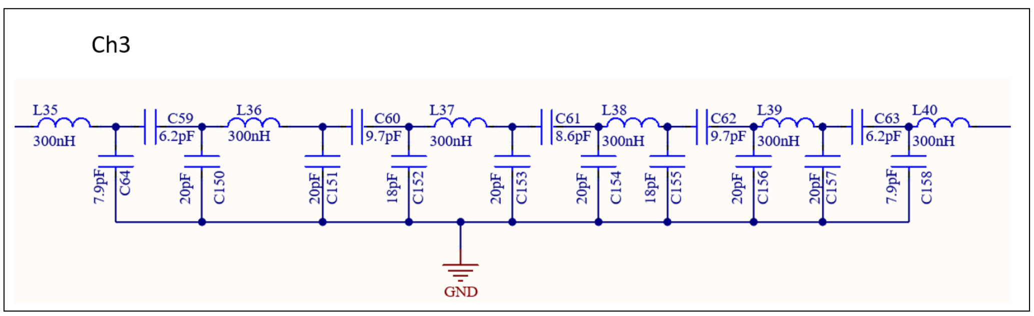


**Fig. 10.** Band pass filter channel 3

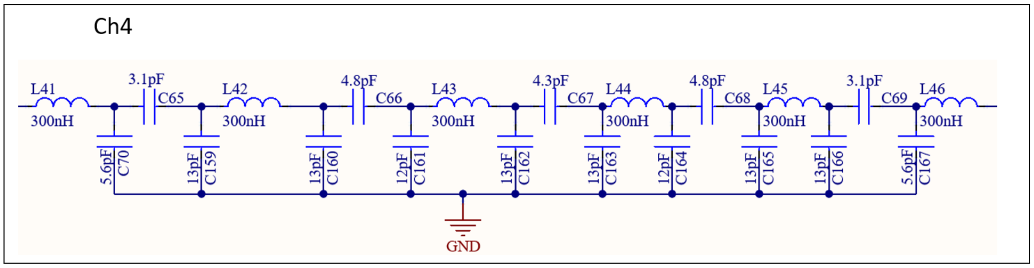


**Fig. 11.** Band pass filter channel 4

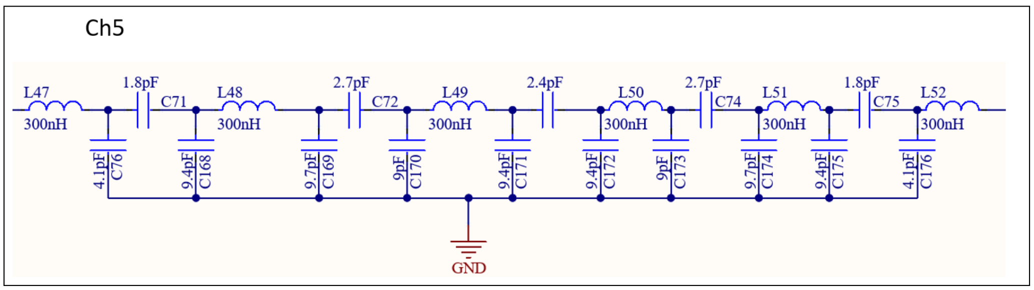


**Fig. 12.** Band pass filter channel 5

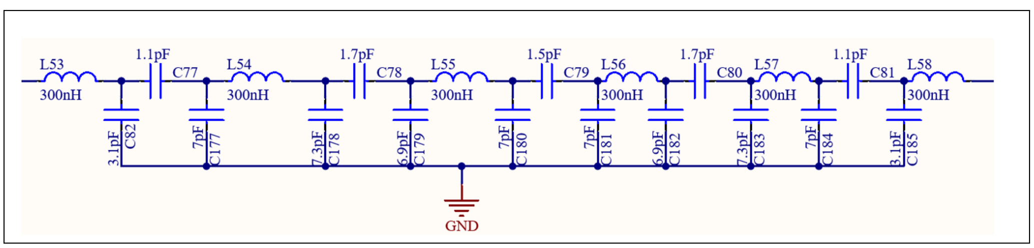


**Fig. 13.** Band pass filter channel 6

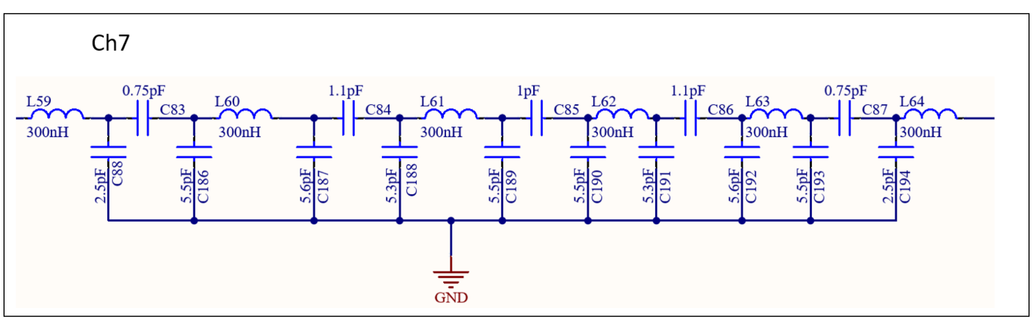


**Fig. 14.** Band pass filter channel 7

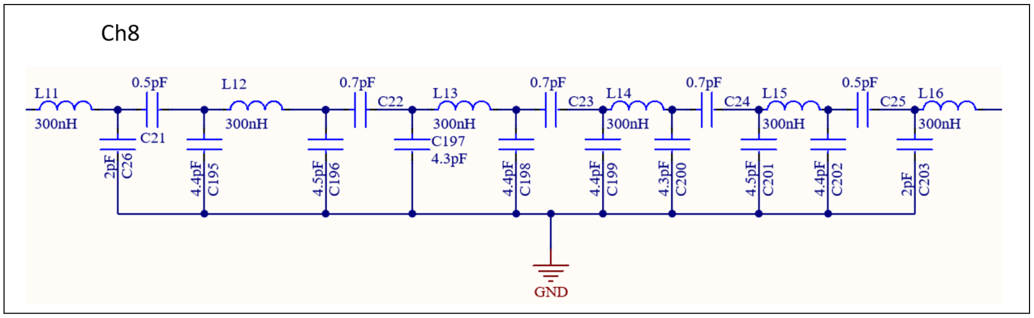


**Fig. 15.** Band pass filter channel 8

### B. Data location