Low Noise DC to DC Power Supply for VHF RF Transceivers

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1. Introduction

Swarm Technologies Inc. produces a VHF satellite modem that uses a modern highly sensitive transceiver. There are a number of new high-performance DC to DC voltage converters that can operate without a RF down-conversion state. This provides an option for low cost small footprint design over traditional low noise-designs. The DC power supply design for the Tile satellite modem ideally will require a switch mode converter to achieve conversion efficiencies for use with batteries. Switch mode converters need special attention for the receiver in the Tile satellite modem to protect from radiating or conducting unwanted RF into the receiver.

2. Power-supply Chain in a Traditional Low-Noise Design

A conventional power-supply design for a VHF RF receiver with low noise performance can contain up to five sections and look as depicted in Figure 1.

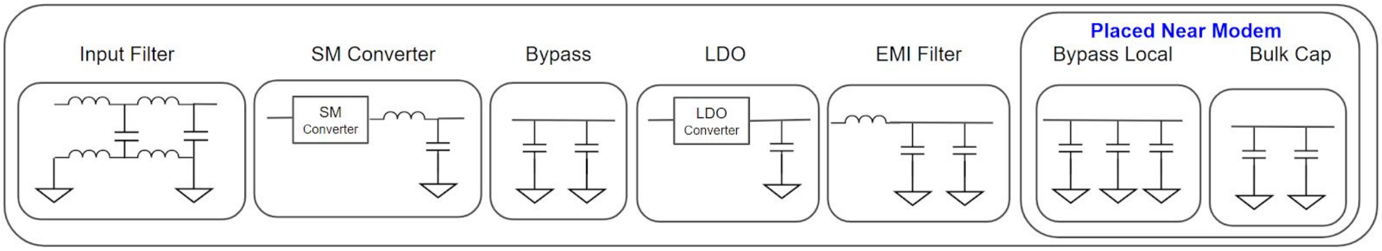

Fig. 1: A conventional low noise DC to DC convertor.

A Low Drop-Out (LDO) regulator reduces the noise contribution of the Switch Mode (SM) DC to DC converter, which will have switching spurs and dynamic noise components. The Low-noise LDO provides a good Power Supply Rejection Ratio (PSRR) at low frequencies, but is less effective at higher frequencies. Bypass or decoupling capacitors provide a local path to ground for noise created by a circuit, decoupling one component or electrical circuit from another. Bypass capacitors provide localized high-frequency bypassing for switching currents generated at the modem. Many moden DC/DC converters use switching frequencies above 1 MHz to reduce inductor sizes. Some modern designs can and should consider using lower frequencies of less than 1 MHz to help eliminate the generation of edge related spurs. At these frequencies, the LDO PSRR may provide up to 20 to 30 dB of insertion loss. Designers can get the same results with optimized power-supply filter designs that eliminate the LDO section. When using switch mode converts with the Swarm Technologies Tile modem the local noise level near the voltage input to the module must be -113 dBV from 120 MHz to 160 MHz.

3. Power-supply Chain in a Modern Low-Noise Design

When removing the low-noise LDO from the power-supply chain, the power-supply filter needs to provide about 30 to 40 dB of rejection at the switching frequency in order to make up for the missing LDO PSRR.

As Figure 2 shows, the power-supply filter was tuned for that goal so that the overall spur performance would be comparable or better than using a low-noise LDO. The filters used have a low overall parasitic component and good insertion loss in excess of 40 dB and are based on feed-through capacitors. It is also important to note that a larger inductor reduces output ripple, which reduces the spurs at the output with a cost of increasing physical size of the inductor and the overall power supply design. It is highly recommended to provide localized transient support for the Tile in the form of localized bypass capacitors and bulk capacitance. Bulk capacitance is commonly used to buffer loadside transients from slower responding DC to DC converters.

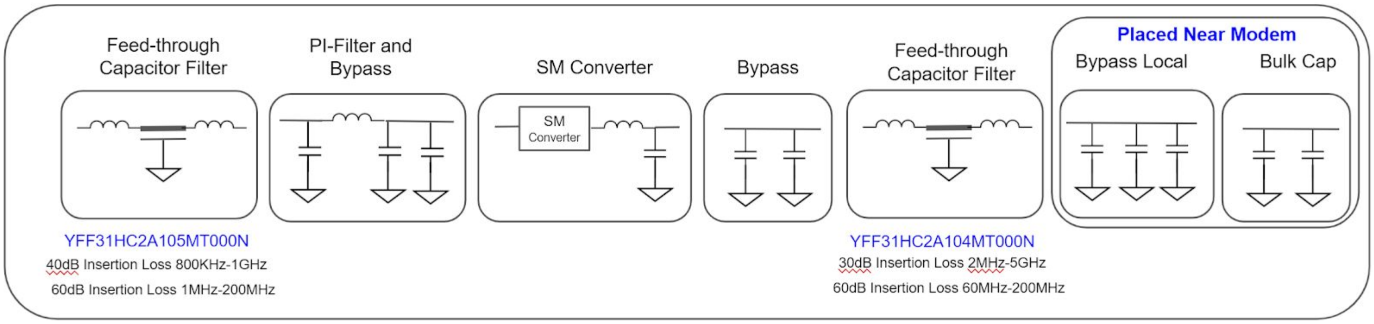

Fig. 2: A modern low noise DC to DC converter without an LDO

As Figure 3 shows, there is a need for a switch mode converter shield that helps to prevent radiated interference from interfering with the Tile receiver input. The receiver input is the antenna, any radiated interference of more than -120 dBm within 137 to 139 MHz and -70 dBm from 120 MHz to 150 MHz at the antenna can result in decreased receive sensitivity. It is also important to ensure that all switch mode supplies and other unintentional radiators are suppressed to prevent unintended interference to the receiver input. In the example below, a shield is used to cover the switch mode DC to DC converter and its main components.

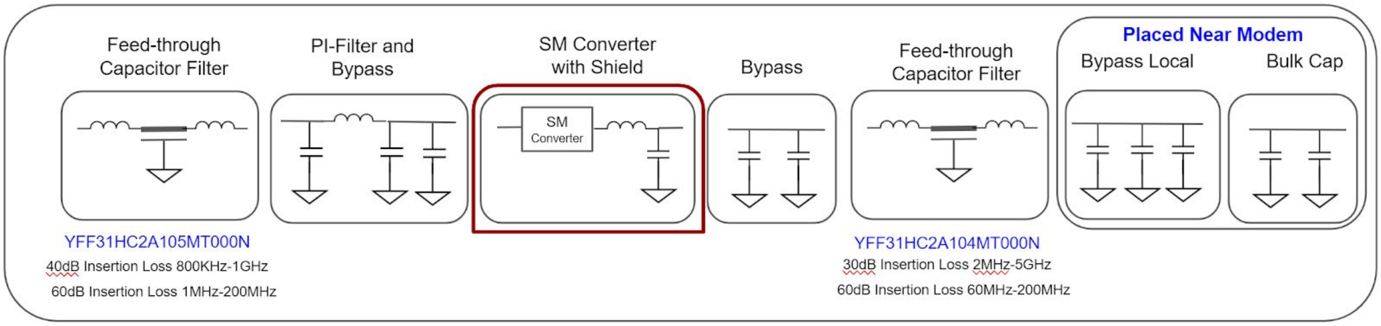

Fig. 3: A modern low noise DC to DC converter with RF shielding

With this design and the precautions taken to suppress and or prevent unintended radiated interference to the receiver input and any conducted interference a test plan needs to be implemented to ensure that the design has been properly implemented.

4. Example 1: Buck-only Low-Noise Power-supply

An example power supply is provided in Figure 4 that is designed to be used with a simple design that either employs a direct DC supply or a Primary Battery source.

- **Type of Design:** Compact Switch Mode Buck DC/DC converter Low Frequency Design
- **Noise Levels:** Spur Noise Levels lower than -113 dBV in the range 137 to 150 MHz
- **Voltage Input Range:** 3.8 V to 28 V
- **Power Source:** Primary Batteries (L91) 4 to 8 cells, USB C, or Wall-Power
- **Power Output:** 3.3 V @ 1.5 A max continuous, Iq=25uA, 90% efficiency for loads more than 10 mA
- **Cost:** As low as $2 in volume
- **Difficulty:** This design is simple to slightly more advanced to implement.

The following design is presented as a known good working design for a Swarm Tile modem that can meet the requirements listed above. The design utilized for conducted spurs suppression both a feed-through capacitor and a Pi-filter to help prevent passing on spurs from the originating power source that may continue through the switch mode converter. These filters are intended to suppress spurs from 800 kHz to 1 GHz by as much as 40 dB. A low frequency compact switch mode buck converter based on the LM60430AQRPKRQ1 has been selected that is designed to efficiently manage low quiescent loads and ensure low noise outputs over a broad spectrum from 800 kHz to 1 GHz. On the output of the converter additional bypass capacitors are used along with an optimized feed-through capacitor that is designed to maximize the noise suppression for the intended satellite operating frequencies of 137 MHz to 150 MHz.

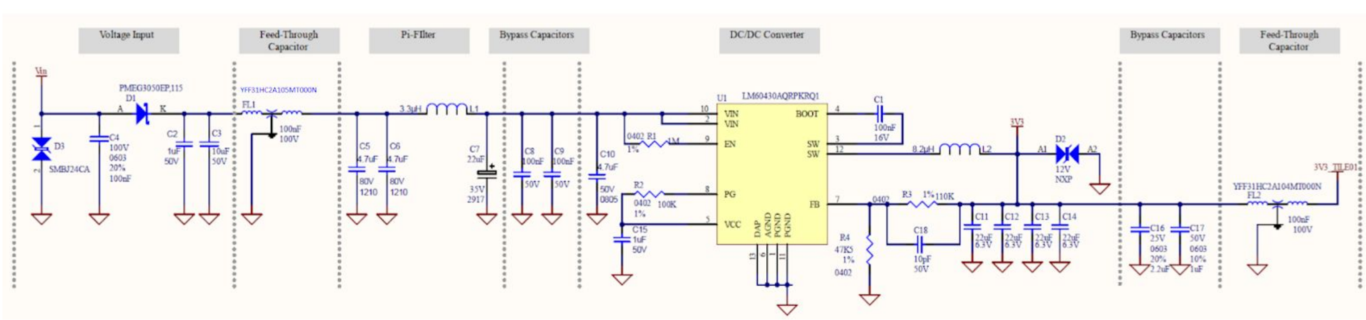

Fig. 4: A buck-only low-noise power supply chain schematic example

Figure 5 contains the shield that covers the switch mode DC to DC converter to prevent radiated emissions that may be generated at the converter from interfering with the Tile receiver input. It is important to note that localized bypass capacitors and bulk capacitance should be used to both suppress additional unwanted high frequency noise from getting on the Tile modem module and to prevent loadside transients from over burdening the DC to DC converter. Bulk capacitance can be as low as 200 uF and as large as 440 uF for this design.

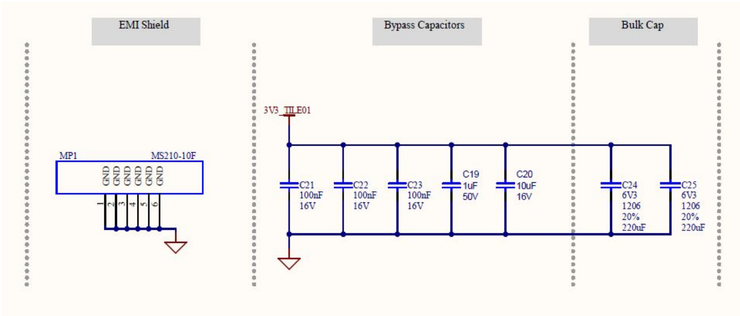

Fig. 5: RF shielding and load side transient support example

The layout of the design should follow the LM60430AQRPKRQ1 datasheet layout instructions. Figure 6 is an example of the layout based on the aforementioned example power supply. The layout includes the DC to DC convert, the input bypass capacitors and output capacitor that are all contained within an RF shield.

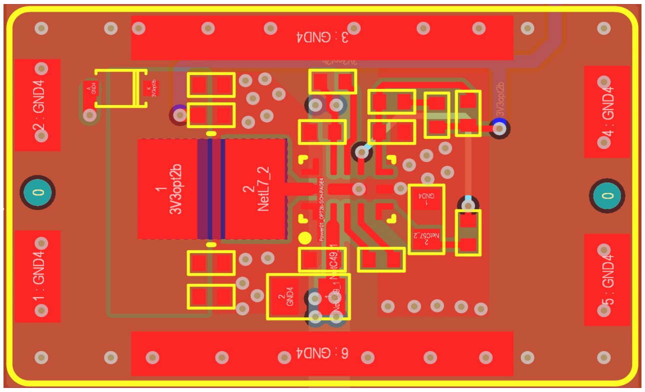

Fig. 6: A buck-only low-noise power supply layout example

5. Test Procedure

To perform a validation for low noise for the example power supply the following test equipment or equivalent is need:

- FFT Analyzer: Picoscope - 5444D
- Digital Load: Rigol - DL3021A
- Power Source: Rigol - DP712
- Barrel Test Tips: CAL TEST ELECTRONICS - CT3672
- Near Field Probe: BEEHIVE ELECTRONICS - 100C
- Spectrum Analyzer: Siglent - SSA3000x
- VHF ¼ Antenna: Provided with Evaluation Kit

The power supply needs to be tested from 0 MHz to 200 MHz using an FFT spectrum analyzer under various loads. The basic test setup is as seen in Figure 7.

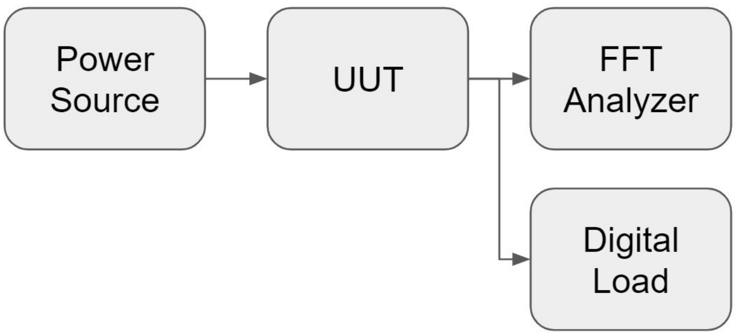

Fig. 7: A power supply validation test setup example

It is important that when connecting to the 3.3 V output at the end of the power supply chain near the input to the Tile modem module that a Tip and Barrel connection be used with the scope probe to limit external interferences from radio stations and other local equipment. The use of the 'Tip and Barrel' is depicted in Figure 8 along with a common kit for a tip and barrel ground pin probe adapter.

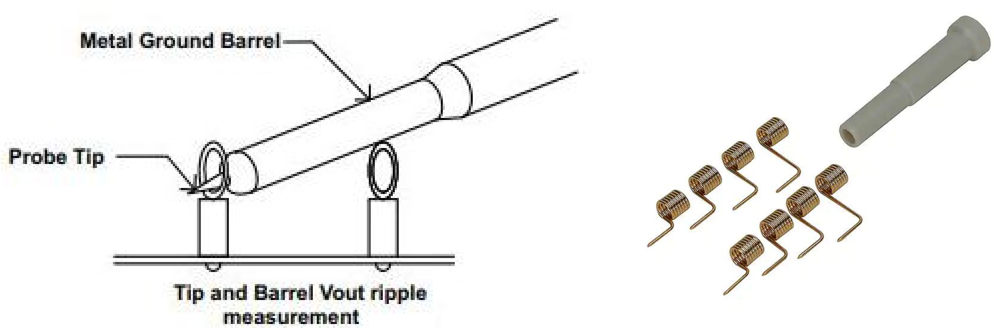

Fig. 8: A tip and barrel power supply test setup and example

Once the connection is made to the voltage output using the tip and barrel connection, the set up for the FFT spectrum analyser should be set to have a span of 0 MHz to 200 MHz, with a minimum of a 65536 spectrum bin, using a gaussian window function, maxhold and x and y axis logarithmic scale. Measure the spectral noise levels of the AC coupled wave form of the DC output. An example output see in Figure 9 of the aforementioned example power supply tests with a 4.5 V bench supply DP712 and with a 1.5 A resistive load provided by the digital load DL3021A and shows a noise level of -115 dBV for the 137 MHz to 150 MHz spectrum.

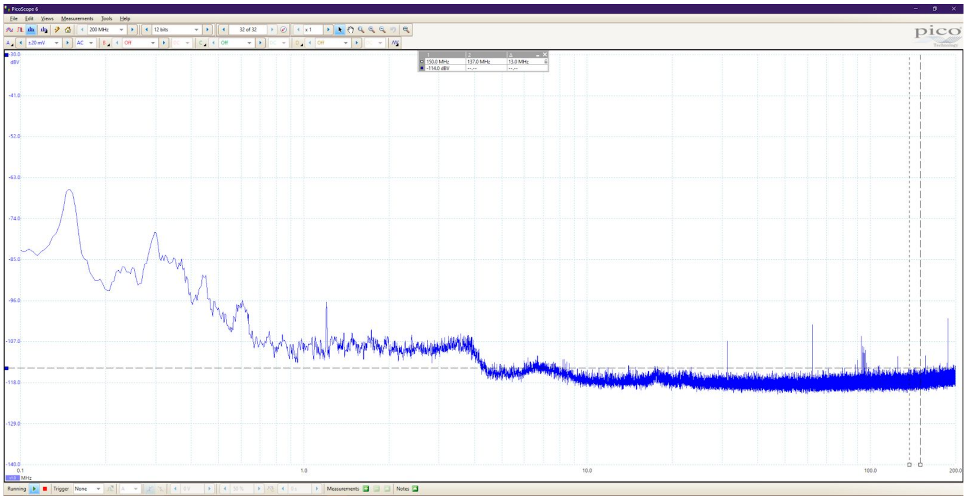

Fig. 9: An FFT spectral output in dBV buck only low-noise power supply example

Similar tests should be conducted that validate the full range of voltage and current loads for the power supply. Tests should be conducted for the expected temperature range, and expected load side transents. It may be necessary to use a near field probe to ensure that there are no radiating components on the host board that are not accounted for, this procedure can also be done using the same FFT spectral analyzer setup. If there are radiating components consideration may need to be taken to either select alternatives to the design for said components or provide sufficient RF shielding to prevent radiated interference to the VHF satellite receiver. The ¼ antenna provided with the Evaluation Kit can be used with a spectrum analyzer in a quiet environment to search for receiver interference.

A final firmware based test needs to be conducted to validate the receive sensitivity where a dummy load is used in place of the Tile model antena and a firmware based test is run. See Test Note: **RSSI Validation Test 10152020'**

6. Conclusions

Due to the low RF signal amplitude being received from space, a low noise DC to DC convertor must be used to provide a clean 3.3 V power to the Tile. A reference example was provided to developers as a known good DC to DC convertor. To address system power consumption, designers of modern high-bandwidth receivers have adopted a new architecture that simplifies the receiver signal chain and results in reduced system power. Rather than using a low-noise LDO to improve power-supply noise, an optimized passive power filter can achieve similar noise rejection without the 15 to 35% additional power expense.