App Note: Circuit Verification and Debugging
EEC 134

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Introduction: This app note covers the procedures needed to verify that both our RF band circuit and baseband circuit work well before doing any signal processing. The message I want to convey is that don't be upset if the circuit doesn't work at the very beginning, because during debugging we can understand the whole system better.

General Idea: To make the system more compact and easier to debug, separate baseband and RF band circuits are recommended. Also, pin headers are great choice to make the connections between two PCBs as illustrated in Fig. 1 and Fig. 2

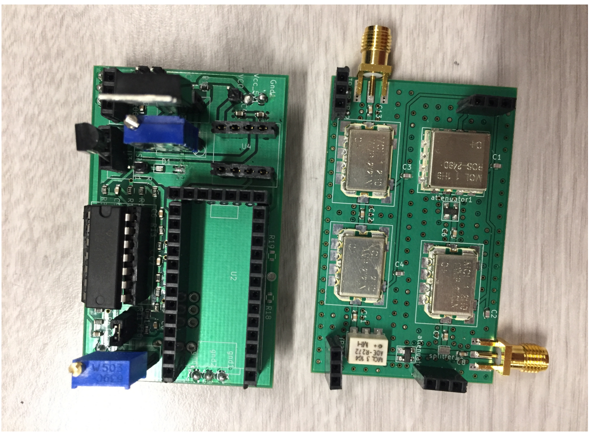

Fig. 1. Baseband & RF PCB

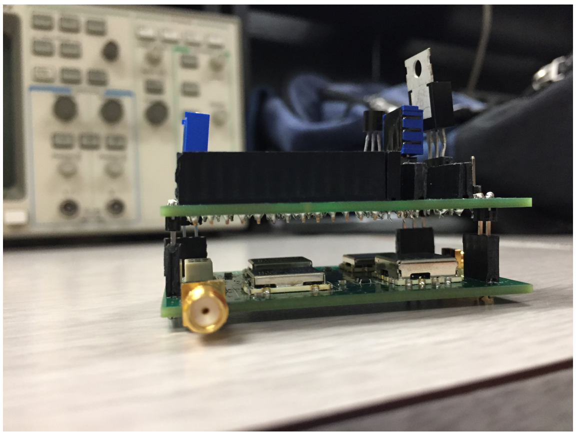

Fig. 2. Stacked PCB

RF band circuit: First step is to verify the transmitter part, which includes voltage-controlled oscillator (VCO), attenuator, low noise amplifier (LNA) and splitter. Based on our power budget calculation, we are expecting to get a power of 15dBm ideally at the antenna. Power on the RF circuit, set the Vtune to 5V, we are able to get 13.7dBm power (excluding the loss of SMA cable) measured by spectrum analyzer shown in Fig. 3. Thus, it's reasonable to say that the transmitter is working properly. Also, VCO needs to be tested to get the actual sensitivity for accurate distance calculation in signal processing.

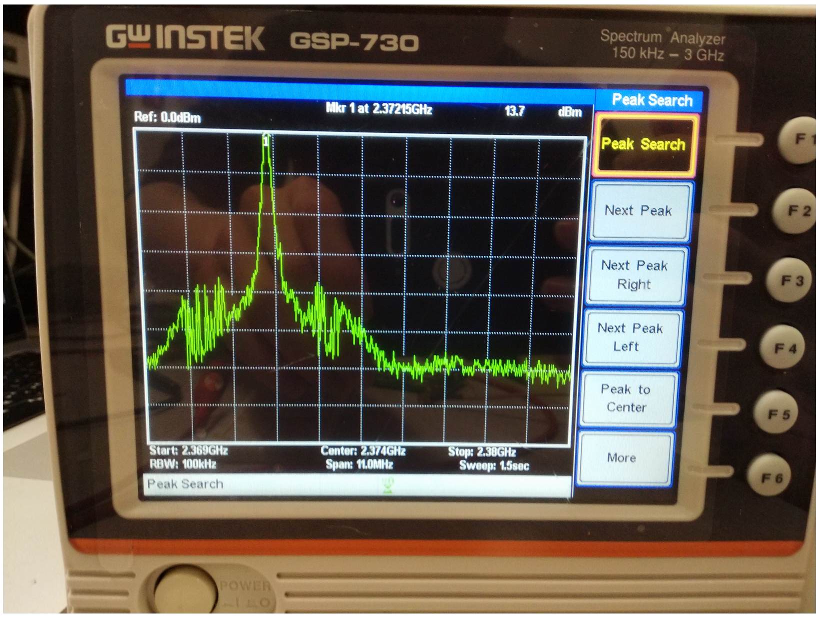

Fig. 3. Transmitted Spectrum when Vtune is 5V

As we sweep Vtune from 0 ~10V, we are able to get the output frequency as show in Fig. 4. The working range of Yagi antenna is 2.4~2.48GHz, accordingly Vtune should vary from 6 to 8V, where the sensitivity is 33.1MHz/V.

Control Voltage/V	Output Frequency/GHz
0	2.2052
0.512	2.224
0.982	2.2352
1.4816	2.2494
2.075	2.2682
2.498	2.2818
3.061	2.3004
3.52	2.3162
4.052	2.3352
4.577	2.3544
5.082	2.3724
5.516	2.3876
6.015	2.4054
6.576	2.4246
7.019	2.4394
7.577	2.4578
8.015	2.4716
8.548	2.4882
8.984	2.501
9.521	2.5166

Sensitivity
33.1 MHz/V

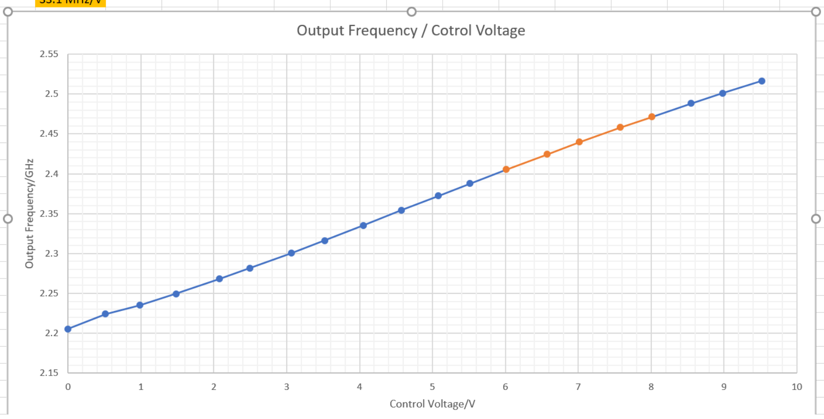

Fig. 4. VCO Output Frequency Versus Vtune

To test the receiver part, which includes LNA and mixer, here is an example: Set the Vtune to a specific DC (5V here), and use TPI synthesizer to generate a power of -35dBm at 2.47GHz. Taking LNA gain and mixer conversion loss into consideration, we are expecting to get -12.4dBm power at 100MHz. So far, our RF should work fine. If something goes wrong, we might need to make a simple probe to test every single component based on power and frequency specifications.

Baseband circuit: The baseband circuit should be able to give desired gain and sufficient bandwidth. Before we have mentioned the sensitivity of VCO to be 33.1MHz/V, Vtune is a 6 to 8V triangle wave at 25Hz. So the maximum frequency that is fed in the baseband circuit would be (this happens when target is 50m away):

$$F\max = \frac{\frac{2*Range}{C}}{\frac{T}{2}} * \Delta V * Sensitivity = 1.1KHz$$

When we feed in a 100mVpp sinusoidal signal to baseband signal, the gain is adjusted to 40 at 1KHz (remain almost same for lower frequency), which results in a 4Vpp output. Vpp reduces to 2.8V when input frequency is around 6KHz as shown in Fig. 5 and Fig. 6. Thus, the bandwidth of the baseband circuit is 6 times of the Fmax, which is sufficient for this system. Similarly, it would be helpful to implement a switch between gain stage and LPF. If something goes wrong, we can test the gain stage and LPF separately like in lab1.

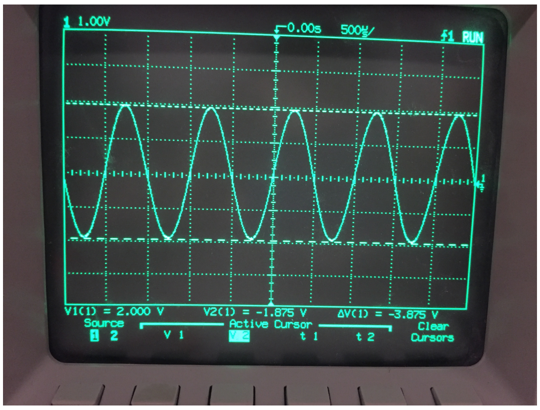

Fig. 5. 1KHz 100Vpp Input

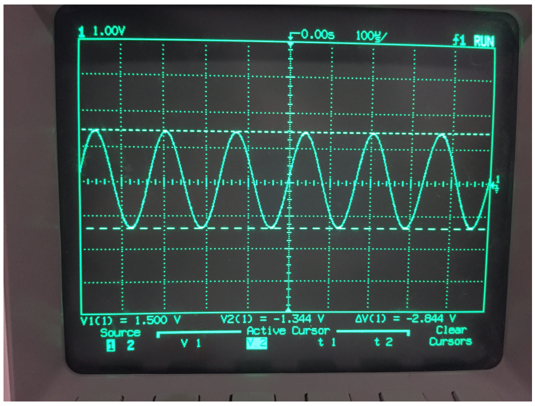

Fig. 6. 6KHz 100Vpp Input

Notice: LT1009 is used for 2.5V reference voltage. The datasheet recommend a 3.6Kohm resistor as shown in Fig. 7. With a 5V input as used in this system, the diode is not able to hold the Vout at 2.5V because if the resistor is 3.6Kohm, the current flowing in diode is much less than reverse current needed as mentioned in datasheet. Instead, a 0.5 to 1Kohm resistor is recommended.

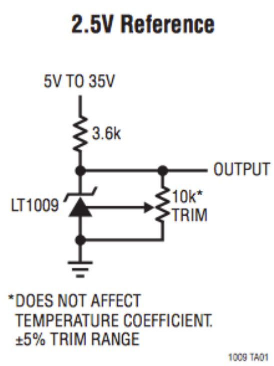

Fig. 7. LT1009 Circuit