DESIGN OF ULTRA-WIDEBAND AMPLIFIER IN RF FRONT END FOR BUNCH-BY-BUNCH MEASUREMENT*

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Abstract

RF front end is one of the key technologies in beam diagnosis, especially in bunch-by-bunch measurement at storage ring. This paper gives the design of ultra-wideband amplifier in RF front end for bunch-by-bunch measurement at SSRF. Simulation have been done to verify the performance of this design.

INTRODUCTION

Beam diagnosis system, with which many accelerator parameters can be obtained, is essential for an accelerator system. Brightness and stability are key specifications of synchrotron radiation light source [1]. Whereas the knowledge of coupling impedance (by which we mean the interaction between a beam and the surrounding vacuum chamber) indicates that the probability of improving performance of storage ring is limited by complicated beam surroundings. What caused the beam unstable, and how to cure the beam instabilities are the key questions, which all the accelerator researchers around the world need to face.

Realizing the measurements of the bunch by bunch position and charge will help study the beam impedance, coupling instability and nonlinear dynamics quantitatively, and can provide the accelerator physicists with an incredibly powerful machine study tool.

In previous experiments, A bunch-by-bunch beam position acquisition system at SSRF has been developed. The BPM raw data and the bunch-by-bunch position have been measured [2]. The system resolution is better than 10 µm and beam instability of multi-bunch can be observed. To improve the accuracy of position measurement we need to design wideband amplifiers to amplify the origin beam signal to close to the full scale of ADC. This paper gives the design of ultra-wideband amplifier in RF front end for bunch-by-bunch measurement in detail.

DESIGN OF POWER SUPPLY

Operational amplifier should be dual power supplied. For the power supply, positive supply is easy to get, while the negative power supply is more difficult. To realize the negative power the power source must be AC power, and then converted to negative DC power supply. In fact the DC power supply itself is obtained by the same way and we can purchase ready-made modules. We use AC power to design the positive and negative power supply at the same time which is a ±2.5V power supply design.

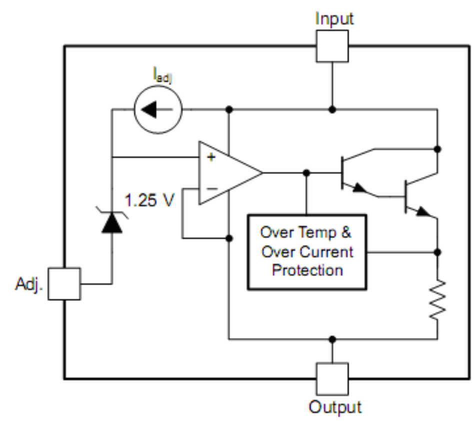

Figure 1: Functional block diagram of LM317.

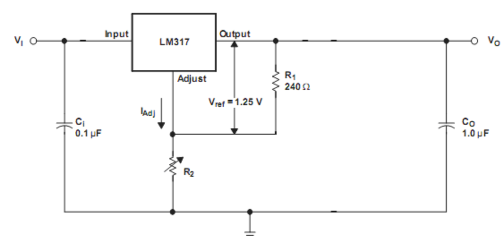

Figure 2: Typical application of LM317.

We use linear power supply LM317 as positive power voltage regulator. Figure 1 shows the functional block diagram of LM317. The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

Figure 1 and 2 shows the typical application of LM317. V_O is calculated as shown in Equation 1. I_{ADJ} is typically 50 µA and negligible in most applications.

$$V_o = V_{REF}\,(1+\frac{R2}{R1})+(I_{ADJ}\times R2) \qquad (1)$$

Wherein: VREF is the reference voltage 1.25V.

C_i is recommended, particularly if the regulator is not

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in close proximity to the power-supply filter capacitors. A 0.1μF disc or 1μF tantalum capacitor provides sufficient bypassing for most applications, especially when adjustment and output capacitors are used. C_O improves transient response, but is not needed for stability.

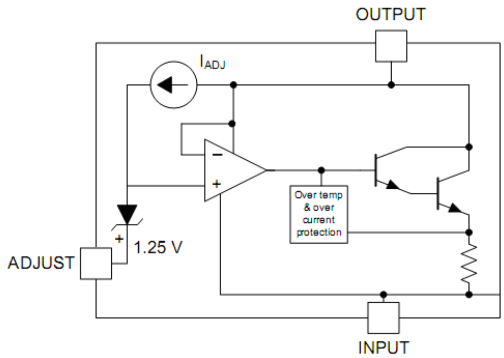

Figure 3: Functional block diagram of LM137.

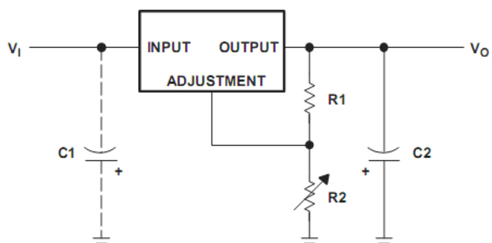

Figure 4: Typical application of LM137.

LM137 is used as negative power voltage regulator. Figure 3 shows the functional block diagram of LM137. The LM137 devices are adjustable 3-terminal negative-voltage regulators capable of supplying in excess of − 1.5A over an output voltage range of − 1.2 V to − 37 V. It is exceptionally easy to use, requiring only two external resistors to set the output voltage and one output capacitor for frequency compensation. The current design is optimized for excellent regulation and low thermal transients. The LM137 devices serve a wide variety of applications, including local on-card regulation, programmable output-voltage regulation, and precision current regulation.

Figure 4 shows the typical application of LM137. V_O is determined by the values of R1 and R2. Choosing R1 = 120 Ω means that about 10.42 mA of current will flow through R1. The ~10 mA of current satisfies the minimum operating current and renders I_{REF} negligible. Since the current is coming from ground, the same amount of current will flow through R2. Therefore, the size of R2 will be the dominant factor in adjusting V_O. The relationship between R1, R2, and V_O is as follows:

$$R2 = R1\left(\frac{V_o}{-1.25} - 1\right) \quad (2)$$

where V_O is the output in volts.

Figure 5 gives the Pspice simulation of power design. The power source is AC power output whose peak to peak value is 12V and the frequency is 50Hz. Diode is used to rectify the AC power, through forward and reverse connection the sine wave voltage is rectified to positive half cycle and the negative half cycle. Half sine wave voltage is then filtered into a DC voltage by the resistor and capacitor low-pass filtering effect. The voltage ripple is relatively large after the resistor and capacitor low-pass filters. So the linear regulator is used to obtain stable DC voltage output. Different colors of the probe are used to measure the voltage on each node.

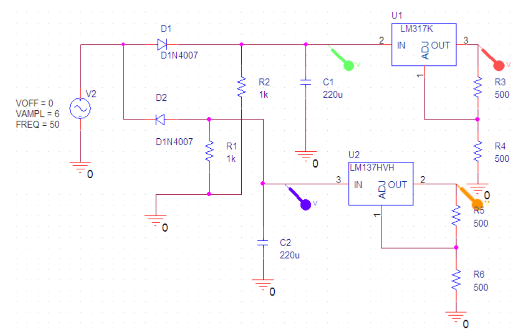

Figure 5: Pspice simulation of power design.

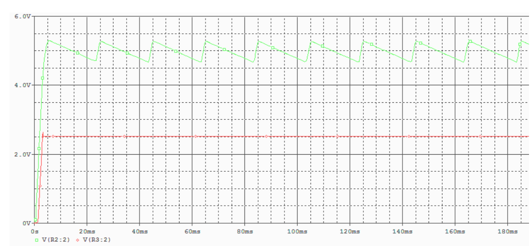

Figure 6: Simulation result of positive power supply.

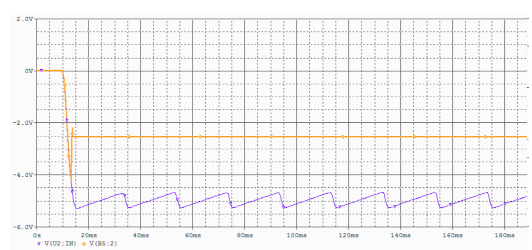

Figure 7: Simulation result of negative power supply.

Simulation result of positive power supply is shown as Figure 6 and negative power supply is shown as Figure 7. And from Figure 6 and Figure 7 we obtain the ±2.5V power supply.

DESIGN OF AMPLIFIER

LMH3401 is used as ultra-wideband amplifier. Figure 8 shows the functional block diagram of LMH3401. The LMH3401 is a very high-performance, differential amplifier optimized for radio frequency (RF) and intermediate frequency (IF) or high-speed, time-domain applications with signal bandwidths up to 2 GHz and small-signal bandwidth of 7 GHz. The necessary feedback (RF) and gain set (RG) resistors are fabricated on the device silicon and provide 16 dB of gain when configured for single-ended inputs driven from a 50-Ω source. When used in a fully-differential configuration, 12 dB is obtained when matching the input to a 100-Ω differential. The on-chip resistors simplify PCB implementation and ensure the highest performance.

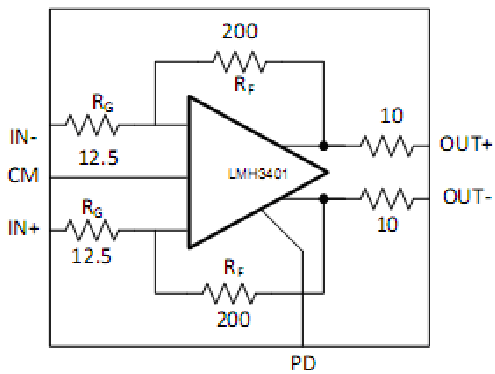

Figure 8: Functional block diagram of LMH3401.

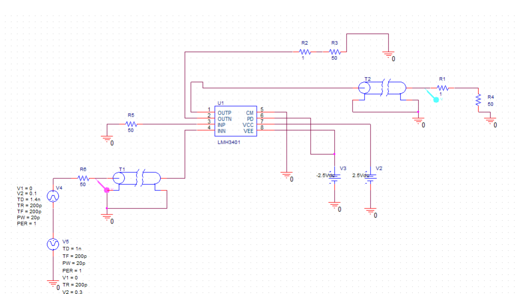

Figure 9: Pspice simulation of amplifier design.

Pspice simulation of amplifier design is shown in Figure 9. For wideband amplifier design, to make the signal without distortion, input and output impedance matching is also very important except for considering the amplifier bandwidth. In Figure 9, we add the 50ohm transmission line T1 and T2 to observe the impedance matching. The delay of the two transmission lines are all set to 3ns, which can be used to simulate the situation when the cable is connected to the amplifier.

The input signal in the simulation is two triangular pulse signal. The rise and fall times of the signal are 200ps. The negative peak of triangular signal is 300mV and the positive peak is 100mV. the output impedance of the signal is 50ohm, so the voltage drop to half of the original when the signal transmission to the cable with 50 ohm characteristic impedance.

Simulation results is shown in Figure 10. The signal is reverse amplified and the magnification factor is 2.66. Simulation results is shown in Figure 10. The signal is reverse amplified and the magnification factor is 2.66. The top of the amplified signal is not an original triangle but a small arc because the bandwidth of the amplifier is not enough to make the triangle signal not distorted. The total width of the amplified signal is 1ns which is less than the interval of two bunch at SSRF. And if the magnification is still not meet the requirements, cascading a number of such amplifiers can be used.

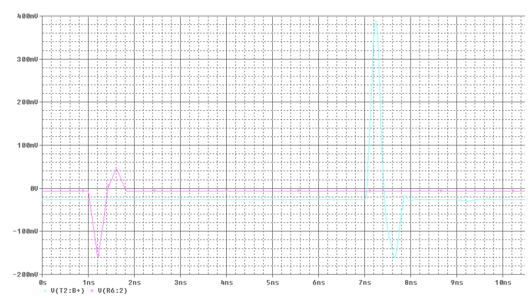

Figure 10: Simulation result of amplifier.

CONCLUSION

To improve the accuracy of position measurement in bunch-by-bunch experiments at Shanghai Synchrotron Radiation Facility, we design a wideband amplifier to amplify the origin beam signal to close to the full scale of ADC. LM317 and LM137 are used as voltage regulator to achieve ±2.5V power supply. LMH3401 is used as ultra-wideband amplifier. Simulation result shows that The total width of the amplified signal is less than the interval of two bunch at SSRF. Practicality fabricating and beam experiments will be done in the future.

REFERENCES

[1] Yang Guisen, Leng Yongbin, Yuan Renxian, Yan Yingbing, “Beam Instabilities Based on Spectrum of Turn-by-turn Position,” High Power Laser and Particle Beams, 08(2011)23.

[2] YANG Yong, LENG Yongbin, YAN Yingbing, ZHOU Weimin, YUAN Renxian, CHEN Zhichu. Development of the bunch-by-bunch beam position acquisition system based on BEEcube. Nuclear Science and Techniques.