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DEVELOPMENT OF AN ANALOG SWITCH GATING A SINGLE BUNCH

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1. Introduction

Most storage machines require a multi-bunch operation in order to achieve a high intensity. KEKB[1] also requires a multi-bunch operation, where about 5000 bunches will be filled in rf buckets with a period of 2 ns. It is not guaranteed that stored bunches have always the same intensity and the same position. Therefore, it is important to measure the beam parameters of each bunch. There would be two methods to obtain the beam information on each bunch. The first one is to sample successive bunches with a rate of more than 500 MHz and store data in a memory bank after digitalization. The second as an alternative method is to pick up a specified bunch with a ultra-fast gating switch. A gated signal is slowly processed within one revolution. A switching time should be much shorter than a bunch spacing time. Changing timing of a gate pulse responds to other bunches. The former is applied for the bunch-by-bunch feedback system[2,3]. However, it would be technically difficult to convert sampled data to a normalized position signal in real-time. The latter technique using a gate is described here. This technique is adequate for measuring a specified bunch in real-time, but cannot measure all bunches at the same time.

2. Analog Switch

In order to pick up one bunch under a multi-bunch operation, a switching time of less than 1 ns is required in the KEKB. However, commercially available analog switches using PIN diodes and GaAs FETs do not satisfy the requirement. A fast analog switch using Si-bipolar transistors with fT of 10 GHz has been developed[4] for a burst modulator. A switching time was obtained to be 1.2 ns. The on/off isolation was more than 60 dB at 200 MHz. Circuit configuration of the switch has been kept and the transistors used in the circuit were replaced by those with higher fT of 35 GHz in order to shorten the switching time. Fig.1 shows the circuit of the ultra-fast analog switch. The circuit consists 12 transistors. The transistors from T3 to T6 control the switch by comparing the voltage externally applied at J1 with the In order to pick up one bunch under a multi-bunch operation, a switching time of less than 1 ns is required voltage VR1. The switch is off when the voltage at J1 is zero and on at -0.7 V. An rf signal passes through from J2 to J3. The bias voltages VCS1 and VCS2 are used for adjusting offset voltages of an output signal.

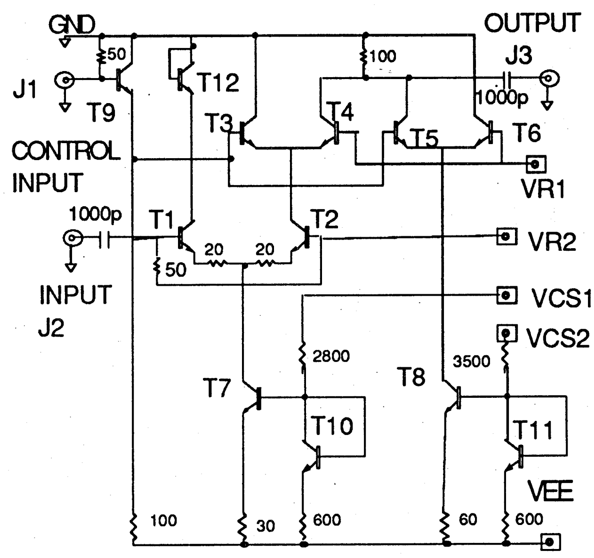

Fig. 1 Circuit of analog switch.

3. Performance

The switch has been manufactured as a monolithic IC and packaged in a case of 9.3 mm square with 21 pins. A frequency response was measured using a network analyzer. Fig. 2 shows transmission loss (S21) with on and off. The insertion loss is about 11 dB up to 1 GHz. The on/off isolation is about 40 dB at 500 MHz and is getting worse as frequency increases. The isolation is worse than that expected in a simulation, which may be due to stray capacitances.

A transient response was tested. A continuous rf wave of 508 MHz was prepared and divided into two ways. One is applied to the switch input J2 and the other to a frequency divider. The divider produces a pulse corresponding to the revolution frequency by doing 1/5120, where 5120 is the harmonic number of KEKB. An output pulse of the divider is used as a trigger of a gate pulse. Rise and fall times of the gate pulse which synchronizes with the rf wave should be much faster than the bunch spacing time. The switching time was less than 200 ps. Switching noises were observed in an output signal of the switch. The noises shaping a spike were reduced by a low-pass filter of 800 MHz. Fig. 3 shows an example of the transient response. We may notice that a continuous wave is converted to a mono-pulse. Table 1 summarizes specifications of the analog switch.

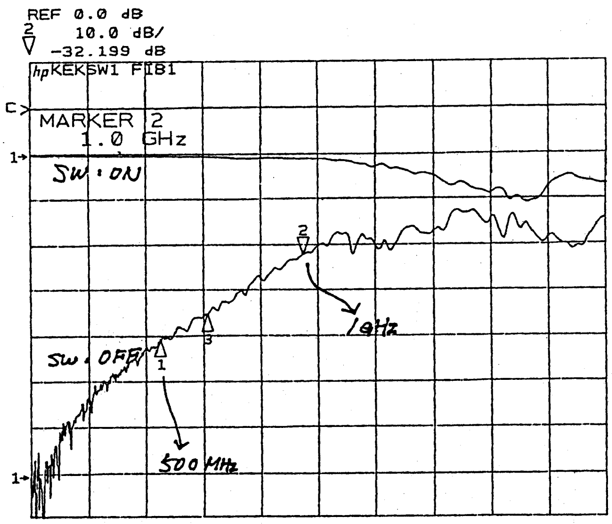

Fig. 2 Frequency characteristics. Horizontal frequency range is 0.05 GHz to 2.05 GHz. Vertical scale is 10dB/div.

Table 1 Specifications of the switch.

Input/Output Impedance	50 Ω
Input Amplitude	0.7 V p-p max.
Bandwidth	1.0 MHz to 1.0 GHz
Control	0 to -0.7 V
Switching Time	200 ps max.
ON/OFF Isolation	40 dB min. at 500MHz
Insertion Loss	11 dB
Power Supply	200 mW

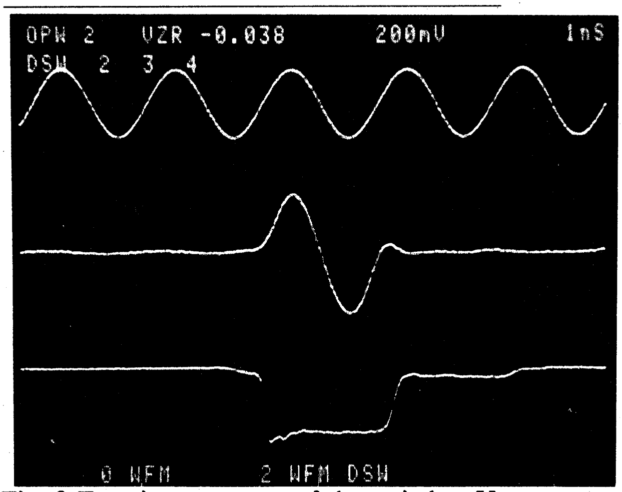

Fig. 3 Transient response of the switch. Upper trace shows an input rf signal of 500MHz with 400mV/div. Middle one is a gated output signal with 50 mv/div. A low-pass filter of 800 MHz is used. Lower one is a gate pulse with 1V/div. All traces are swept with 1ns/div.

4. Signal Processing

Two techniques to detect a beam pulse are widely used. One is a narrow-band method, where a specified frequency component of a beam pulse is detected with a band-pass filter. The other is a wide-band technique, where a pulse height or area of a pulse is detected. Let's compare the S/N in both techniques assuming that one bunch is gated with 2 ns gate width and the signal process is carried out within one turn (10 μs). The bandwidth is more than 100 kHz. The thermal noise level is proportional to square root of the bandwidth. On the contrary, a signal amplitude in the frequency domain is approximately reduced to the duty factor(2x10E-4) in the time domain. Therefore, the wide-band detection in the time domain has an advantage for the S/N ratio in a turn-by-turn measurement.

One example of the turn-by-turn measurement is shown in Fig. 4. The apparatus will be able to measure the betatron tunes as is used in TRISTAN[5]. A beam pulse is picked-up by a button electrode and will be stretched out by a coaxial cable. Low-pass filters also stretch the beam pulse further so as not to overlap successive bunches. A low noise amplifier is needed in order to compensate the loss occurred at the gate. The BOD[6](Bunch Oscillation Detector) samples the gated beam pulse with a self-produced pulse and holds its peak voltage. The BOD can detect AC components of a normalized beam position with a help of an AGC (Automatic Gain Control) loop. The betatron tune measurement is very important an especially in the components of a normalized beam position with a help of an KEKB since the beam-beam tune shift gives us a transverse beam size at a colliding point.

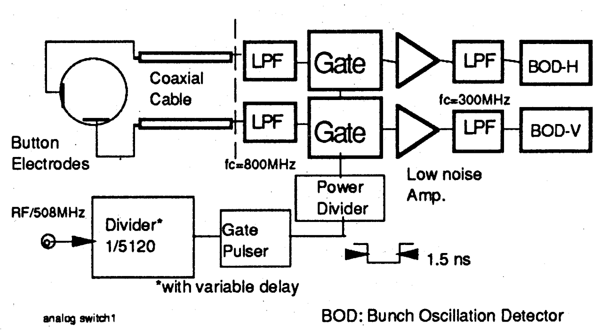

Fig. 4 Block diagram for detecting the betatron tunes.

As a summary, we have developed an analog switch for gating a single bunch. The gating switch has the switching time of 200 ps. The on/off isolation was 40 dB at 500MHz. This switch would be used for monitoring a bunch intensity and the betatron tunes in real-time.

References

[1] KEKB Design Report, KEK Peport 95-7 (1995).
[2] E. Kikutani and Y. Minagawa, KEK Report 94-5(1994).
[3] J. D. Fox et al., Proc. of 1993 PAC, Washington D.C., (1993)p.2076.
[4] H. Kikuchi, NTT Co., private communication.
[5] T. Ieiri et al., NIM A265 (1988)p.364.
[6] T. Ieiri et al., Proc. of the 5th Symp. on Accelerator Science, Tsukuba (1984)p.157.