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Letter to the editor

Power-supply/ground-ripple rejection capability of the SMA^2SH preamplifier array for a silicon micro-strip detector*

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ABSTRACT

The noise characteristic of the SMA^2SH -series preamplifier array has been improved in terms of its sensitivity to external disturbances. An eight-channel version of the SMA^2SH preamplifier was employed for the evaluation. In order to distinguish power-supply disturbance from that coming from ground, we employed variations of an internal biasing circuit for the preamplifier.

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The SMA^2SH preamplifier array has been developed for the B-factory project at KEK as a part of developmental work for a silicon vertex detector.^[2] In the prototyping procedure we fabricated a single-channel amplifier, i.e. SMA^2SH-1 , which showed a smaller signal-to-noise ratio than expected. The measured noise slope was 40 to 50 e/pF, depending on the operation conditions.^[3] The reason for the larger amount of noise was soon identified as common-mode noise,^[4] which was reduced by employing a 64-channel preamplifier array, i.e. $SMA^2SH-64A$. Since the common-mode-subtracted signal-to-noise ratio was very close to the expected value, i.e. 10 e/pF, we confirmed that the circuit configuration as well as its operating conditions are appropriate. In order to minimize the dead-time fraction due to the readout procedure of the BELLE DAQ system, we plan to employ a sparse data readout; thus, a common-mode-subtraction scheme will not work. In order to identify the reason for the common-mode noise and to determine an assessment method for reducing the common-mode noise, we studied a new circuit design which included a stabilized biasing circuit, which had the capability to reject any power-supply ripple. The test chips were eight-channel preamplifier arrays, SMA^2SH-1 , $SMA^2SH-64A$, which shared every circuit design with the SMA^2SH-1 , $SMA^2SH-64A$, and eventually, $SMA^2SH-128$. The SMA^2SH-8X 's were operated with a 100 MHz clock frequency throughout this study.

An equivalent-circuit diagram for a noise-evaluation setup is shown in Figure 1. There are shown two noise sources: one is in between the power-supply terminal and circuit V_{dd} ; the other is located in between the external ground and circuit V_{ss} . The most standard way to evaluate noise has been to use the configuration shown in Figure 1 a). Denoting the power-supply and the ground noise as δ_{dd} and δ_{ss} , we can write the amplitude appearing at the output node of the preamplifier as

$$\delta_{ss} \cdot C_d / C_f + \delta_{dd} \cdot \frac{C_d + C_s}{R_{ref} g_m C_f},$$

where C_d is the externally attached capacitance, C_s the internal stray capacitance, C_f the feed-back capacitance of the preamplifier, g_m the transconductance of

ET for the preamplifier, and R_{ref} the externally located resistance to set current of the preamplifier. It is noted that the two terms in Eq (1) are added together in quadrature for an exact presentation. We would like to mention that the external noise is proportional to the detector capacitance, similar to the thermal electronic noise, and, hence, might be enhanced for a larger size detector. We can set a rough number for Eq (1) where we take $C_d = 12 \text{ pF}$, $C_s = 12 \text{ pF}$, $C_f = 0.2 \text{ pF}$, $g_m = 2.5 \text{ mS}$, and $R_{ref} = 36 \text{ k}\Omega$, $V_{dd} = 1.5 \text{ V}$, and $\delta_{dd} = 0.5 \text{ mV}$. The first and second terms yield 1.5 and 1.2 mV, which are equivalent to 1875 and 1500 electrons, respectively. We find here that the external noise (δ_{ss}) is more sensitive than the power-supply noise (δ_{dd}).

Figure 2 shows two configurations of the biasing circuit for the preamplifier. Figure 2 a) shows the biasing circuit together with the preamplifier configuration, which is sensitive to the V_{dd} disturbance; any variation in V_{dd} is sensed by R_{ref} , which propagates to the output node of the preamplifier. Figure 2 b) has a special function; V_{dd} is sensed only when the amplifier is being "reset" by SW1, and is isolated from the preamplifier by SW2 and SW3 during a period of acquisition. C2 and C3 are used to maintain a constant bias current. With the same mechanism transistors M31-M34, M41-M44, and M51-M54 are operated at a constant current, and, hence, the voltage of the output node remains constant as the circuit refers to V_{ss} as a firm base of the potential.

We first compared two circuit configurations (Figure 2 a) and b)) with a common-mode capacitor (Figure 1 a)). Figure 3 shows the electronic noise charge for the two circuit configurations. We found that there was a significant improvement in the signal-to-noise ratio for the stabilized circuit, though it was still far from the thermal (electronic) noise. Since the two chips showed a similar signal-to-noise ratio and the common-mode noise was subtracted (Figure 4), these two circuits were equally excellent as long as the intrinsic (electronic) noise was concerned. At the same time we came to understand that a large amount of output noise came from the ground-related external noise.

Now considering a practical condition for operating a double-sided silicon detector, every capacitance is located between the input nodes of the preamplifier, there are essentially no grounded capacitors. We tried to move a capacitor between the amplifier (Figure 1 b)), where any ground disturbance (δ_{ss}) should have no effect on the noise at the output node of the preamplifier. We subsequently found a drastic improvement in the signal-to-noise ratio, as shown in Figure 3, which was compatible with the common-mode subtracted noise. It is worth mentioning that a similarly good result was obtained even for the V_{dd} -non-stabilized circuit, since the disturbance from V_{dd} equally influenced the two amplifier channels; hence, the external capacitor (C_d) could not flow any noise current. There was a systematic tendency that the V_{dd} -stabilized circuit showed slightly superior results, which was possibly due to a stray capacitance (C_s) associated with the output node of the preamplifier. The V_{dd} -non-stabilized circuit was still influenced by V_{dd} disturbance through C_s .

The SMA^2SH -series preamplifier chips were confirmed to intrinsically, as well as practically, meet the design goal, which had been difficult to be examined in practice due to environmental disturbances. A special biasing circuit which was free from any power-supply disturbance successfully isolated the ground-related noise from that coming from the V_{dd} disturbance, from which we found that the ground disturbance was the most serious part. By moving a scope to a practical operation condition of a double-sided detector we found that we could safely resolve the problem. The SMA^2SH preamplifier was very calm as long as the detector capacitances were located in between the preamplifier channels, even with the existence of a certain amount of external noise from δ_{ss} and/or δ_{dd} .

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FIGURE CAPTIONS

p for the noise evaluation

round-referenced noise measurement

mplifier-referenced noise measurement

ng circuit for the preamplifier

iginal biasing circuit

biasing circuit free from power-supply disturbance

ured electronic noise with a grounded input capacitor

input capacitance is defined as the sum of C_d and C_s . The open circles
for the bias circuit, as in Figure 2 b), while the plus symbols are for that
Figure 2 a).

non-mode subtracted electronic noise with grounded input capacitors

input capacitance is defined as the sum of C_d and C_s . The open circles
for the bias circuit, as in Figure 2 b), while the plus symbols are for that
Figure 2 a).

red electronic noise with a capacitor between the input nodes of two
mplifiers

input capacitance is defined as as the sum of C_d and C_s . The open
are for the bias circuit, as in Figure 2 b), while the plus symbols are
t as in Figure 2 a).

A)

B)

9

Figure 2

10

Figure 4