Problems and update plan of the Amp-Discri module and related equipments.

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1 Introduction

In the KEK PS-E391a experiment, discrimination of extremely-small signal from the detector is critically important to reduce the background. The E391a group and KEK electronics facility newly developed the module that can discriminate such small signal, so-called 'Amp-Discri-Delay-Sum' module. This module can produce three kinds of output simultaneously from a PMT signal, the analog signal for ADC, timing signal for TDC and analog-sum signal for trigger, so that the cabling in the latter stage of triggering and sequencer logic circuit would become easier.

2 Schematics of the circuit

Figure 1 shows the schematic view of the Amp-Discri-Delay-Sum (Amp-Discri) module. The analog output for the ADC (Through), the delayed logical output for the TDC which is the discriminated signal of amplified analog signal by 36 times, two linear-sum signal and one amplified-sum signal of the 8 channels are shown.

Since the preamplifier is connected to the input signal by AC-coupling, the DC offset of the preamplifier output does not depend on the DC offset of the input signal. Thus the discrimination level of the comparator depends only on the pure pulse-height of the input signal and the internal DC offset of the comparator, but not on the DC offset of the input signal. The internal offset is adjustable by the variable resister, and is adjusted to zero when it is shipped. The fast-response, high-accuracy and small temperature-dependency would be necessary to each electronics parts for our requirements. After some comparison tests, we finally chose the OPA689 as a preamplifier, MAX9687 as a comparator, MC10131 an an ECL IC, SDL300N101 (300nsec) as a logical delay chip, respectively.

On the contrary, the linear-sum circuit is DC-coupled with the input signal. Thus the DC offset of the preamplifier output of the linear-sum depends both on the DC offset of the input signal and on its internal offset. Since the linear-sum output is used as the simple hardware-clustering signal in the latter stage of triggering logic by discriminating with some threshold energy, the stability of the DC-offset level is crucially important in order not to apply any bias in the trigger condition. The DC offset of the linear-sum output is also adjustable by the variable resister. The preamplifier OPA685 is used as a driver.

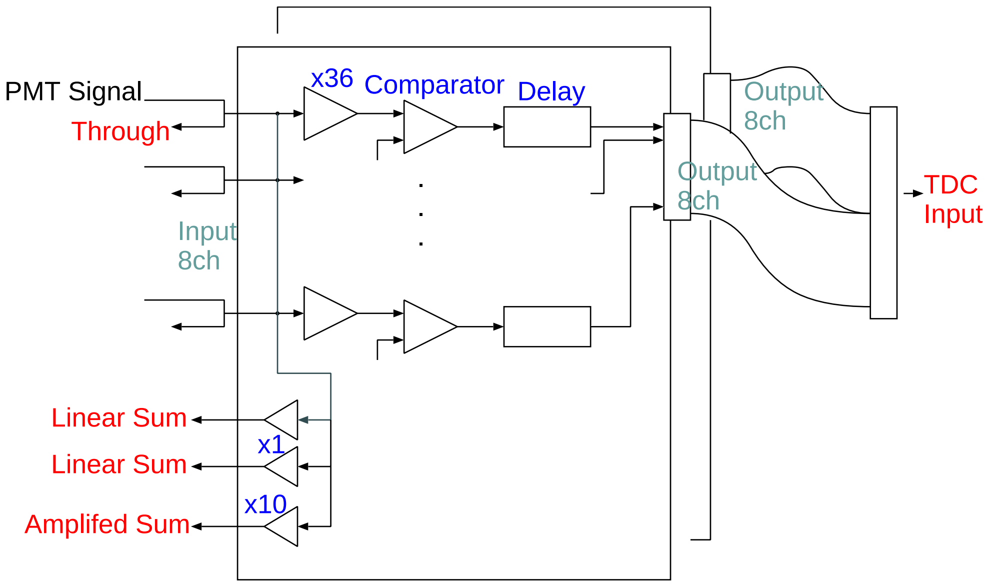

Figure 1: Schematics of Amp-Discri-Delay-Sum module.

3 Specifications

There was a possibility to use the VME or the CAMAC standard as the frame-box of the module, since they have the control-bus in the backplane so that we could control the module settings such as threshold or DC offsets remotely on-line. However, considering seriously that the most important fact is to reduce the noise level on the signal as much as possible, we decided to use the NIM-standard as the frame box of the module since the NIM standard is stronger to the noise than VME or CAMAC system.

Due to the convenience of the connection to the TDC, one module consists of 16 channels. One circuit-board can contain eight channels on its space, thus one module consists of two circuit-board, which requires double-width of a NIM slot.

On the front panel, dual LEMO-type connectors for the input PMT signal and output ADC signal, LEMO-type connectors for the linear- and amplified-sum outputs, trimmers for the adjustment of discrimination level and for the adjustment of the width of the logic signal for TDC are located.

The power requirement is the -6V DC only, and the power consumption is about 15.6 W (2.6 A). The power is supplied by one connector per module, and distributed to two circuit-board inside the module.

The total channels of the E391a detector will be about 900, so we need about 60 Amp-Discri module to process all channels.

The module assembling and production was done by the 'GND' company, and finally 65 modules are prepared until the October 2002.

4 Location

Since the detector signal should be processed by the Amp-Discri module as early as possible to avoid the possible noise, the Amp-Discri modules are installed in the NIM bins located just behind the detector.

In the engineering run at October 2002, we used 45 Amp-Discri modules with 9 NIM bins, and processed about 700 channels of the detector signals.

The detector signal is fed into the input connector of Amp-Discri module by 7 meters of RG175/U cable. The output signal for the ADC is first fed into the patch-panel by 2 meters of RG175/U, then delivered to the other patch panel by 90 meters of the RG58C/U cable, then finally fed into the ADC by 2 meters of RG175/U cable.

The TDC signal is delivered to the TDC directly by the 34-pairs of twisted-pair cable.

One of the linear-sum signal is fed into the ADC by the same way as the detector signals in order to measure the energy sum of 8 channels. The other linear-sum signal is delivered to the triggering logic by the 30 meters of 3D-FB cable, which has faster transmission speed than the RG-58C/U by about 16%.

5 Performance as of October 2002

In the preparation of the engineering run, we observed the several mV of the 50 Hz AC noise on the detector signal when we connected the PMT, Amp-Discri and ADC We recognized that this was due to the so-called ground-loop, so we disconnected the frame-ground from the GND line in the power-supply cable, and reconnected it to the newly-created ground under the detector hall. After this modification, the AC noise has disappeared and remaining noise was almost less than 1 mV level. The pedestal width of the ADC data that is triggered by the random clock has improved from $\sigma \sim 7$ ch to $\sigma \sim 1.4$ ch.

Just after the engineering run started, in order to know the beam-specific noise, we took the data by changing the discrimination threshold of the Amp-Discri module such as 3 mV, 2 mV and 1 mV. No increase of random-hit was observed even with the 1 mV threshold. Thus we judged that no beam-related noise appeared for our equipments, and we decided to apply 1 mV threshold to the CsI detector and 3mV for other detectors.

6 Problems as of October 2002

The amplification, discrimination and delay part of the Amp-Discri module was proved to work as we expected. However, some serious problems appeared in the linear-sum circuit.

6.1 DC offset of the linear-sum output

As is mentioned in the section 2, the DC offset of the linear-sum output is adjustable by the variable resister. In the real setup of our experiment, however, we noticed that in some module the offset could not be adjusted to zero.

The variable range of the DC offset deepened on the resistance of the variable resister itself and two fixed-resistor located before and after the variable resister. The Amp-Discri module uses the 500 Ω of variable resister and 1 kΩ of fixed one in both before and after, so the total resistance is 2.5 kΩ. Smaller resistance makes the range wider, but the resistance will become more sensitive to the temperature, so the 100 Ω will be the limit in reality. Smaller resistance also consume more power.

The variable-range of the Amp-Discri module is about 0 ± 40 mV, so we can adjust it to zero only if the sum of the offset of eight input signals does not exceed this value. The offset of PMT signals shows less than 1 mV, and the offset of ADC cables shows less than 5 mV by measuring independently by the oscilloscope. Thus we thought that all modules can be adjusted to zero, but it is not in reality.

Table 1 shows the DC offset value of each Amp-Discri module (mV) when we adjusted the output offset to the lowest value. All the input and output cables are connected to the module. The colored number indicates that the offset is still plus value even if we adjust it to the lowest value, thus it is not adjustable to zero. 30 channels among the 83 channels have such positive offset.

The possible cause for this will be that the shift of the potential of GND line of each module from the zero may affect to the shift of the output of preamplifier. We noticed that the GND potential of the module differs slot by slot, or even in the two circuit-board in a module. Table 2 shows the potential difference of the GND level of the circuit-board and that of NIM bin's power supply. The DC offset which the preamplifier feels depends on the potential difference between these two levels. The offset on the output of the preamplifier depend on this difference and its internal offset. Figure 2 shows the correlation between the GND potential of the circuit-board and the DC

Left rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4	−22	−10	−30	0	+10	−5	−28	−20	−5	+2		
Bin#3	−8	+12	+16	+24	−6	+40			−23	−24	−40	−33
Bin#2			−14	−5	−2	−5	−8	+6	+12	+22	+8	+40
Bin#1	+15	+25	+15	+45	+15	+60	−20	−8	−15	0	−20	0

Right rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4								−24	−4	+15	+2	−4
Bin#3	−46	−16	−8	+16	+30	+55	−16	−40	−28	−16	−20	−14
Bin#2	−41	−35	−24	−30	−18	−8	−18	+20	−25	+16	+24	+10
Bin#1	−20	−10	−20	−17	+10	+18	−10	+24	−30	−20	−8	+25

Table 1: The offset potential of the linear-sum output of each Amp-Discri module in the NIM bin. The offset adjuster is set to the lowest potential. The colored value indicates the positive offset. 30 out of 83 channels have positive offset.

Left rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4	−14.4	−16.4	−14.7	−16.6	−17.9	−19.8	−14.4	−16.3	−17.3	−19.3	−266	−262
Bin#3	−15.8	−17.7	−17.3	−19.3	−17.4	−19.4	−220	−210	−15.0	−16.9	−13.0	−15.0
Bin#2	unstable		−13.1	−15.0	−12.8	−14.8	−17.0	−18.9	−17.2	−19.1	−13.9	−15.8
Bin#1												

Right rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4	−17.7	−19.6	−193	−193	−17.3	−19.2	−12.0	−13.7	−13.4	−15.3	−12.8	−14.7
Bin#3	−11.6	−13.5	−16.9	−18.8	−25.2	−27.0	−16.8	−18.7	−16.3	−18.1	−13.0	−14.9
Bin#2	−13.6	−15.6	−14.0	−15.9	−16.4	−18.2	−16.7	−18.5	−15.2	−17.4	−16.4	−18.3
Bin#1	−15.0	−16.5	−11.2	−13.1	−21.9	−22.8	−16.8	−18.6	−11.8	−13.9	−17.6	−19.5

Table 2: The potential difference between the GND potential of each circuit-board of Amp-Discri modules and that of NIM bin's power supply. Colored one indicates unstable or extremely large.

offset of its linear-sum output. Although the potential of PMT cable and ADC cable are not taken into account in the GND potential value, correlation can be clearly seen.

We can judge that this problem is not caused by the malfunction of the linear-sum circuit itself, because the offset is adjustable to zero when we attach the 50-Ω terminator to the module input instead of the cables from PMT and ADC.

We can also judge that this problem is not related to the malfunction of the cable or the electronics connected to the input cable like PMT or ADC. This can be confirmed by swapping the two set of input cables to the Amp-

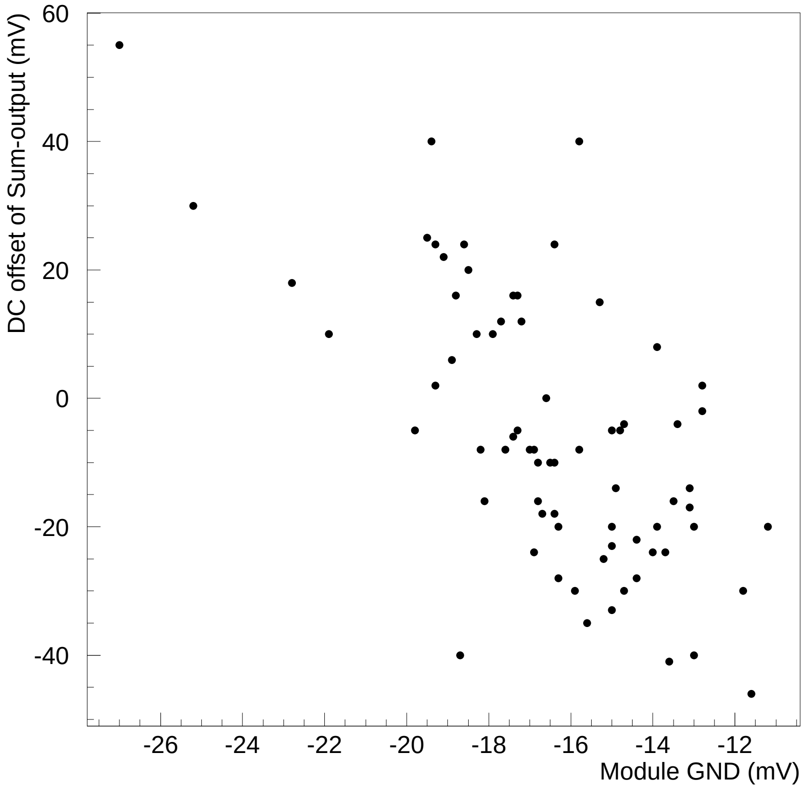

Figure 2: The correlation between the DC offset of the linear-sum output and the GND potential of each circuit-board.

Discri module. We swapped the input cables (PMT-cables and ADC-cables) of channel 0-7 and channel 8-15 in a module, i.e. the input cables for the one circuit-board and those for the other circuit-board, then measured the DC offset of the linear-sum output of each circuit-board. The result is that the offset of ch0-7-side linear-sum was -8 mV even before and after the cable-swapping. The offset of ch8-15-side linear-sum was $+16$ mV, and does not change before and after the cable-swapping. We also tested it by swapping the cable between two modules. We swapped the input cables for the channel 8-15 of the Amp-Discri module in the right-rack, bin#3, slot#0-1, and the channel 0-7 of the Amp-Discri module in the right-rack, bin#3, slot#4-5, then measured the DC offset of the linear-sum output of each circuit-board. The offset of ch0-7-side linear-sum of slot#0-1 was -46 mV even before and after the cable-swapping, and the offset of ch8-15-side linear-sum stayed at $+55$ mV. From these results, we might say that the variation of the DC offset is not related to the malfunction of the cable or the electronics connected to the input cable.

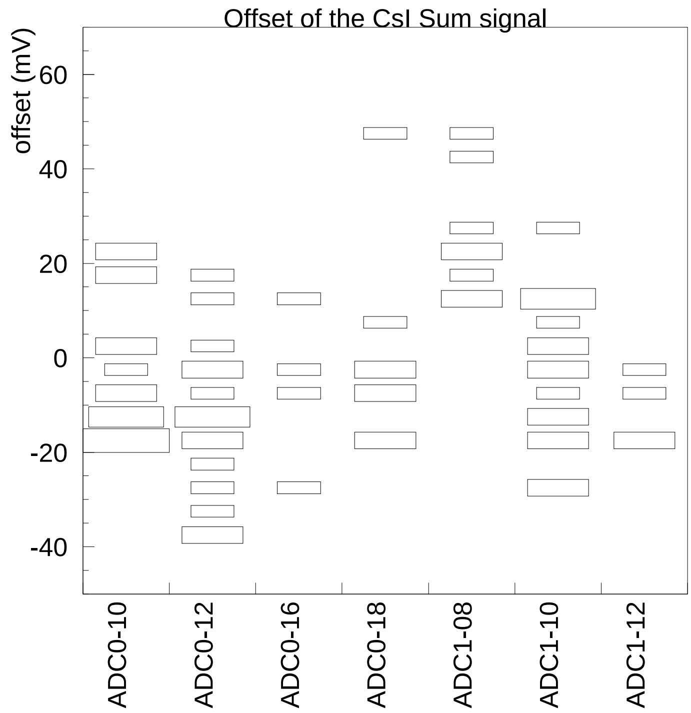

Figure 3: The ADC-module dependency of the DC offset of the 72 channels of the linear-sum output.

We can judge from the Figure 3 that the DC offset does not depend on the ADC module which shows the correlation between the DC offset of the linear-sum output and the ADC modules that the linear-sum output is connected to. One may think that DC offset of the channels which is connected to the ADC 1-08 seems to be rather high. This is however not correct. One of the linear-sum output which is connected to the ADC 0-18 has very high offset value, and this Amp-Discri sits in the same NIM bins as those who are connected to the ADC 1-08. Thus you can conclude that the high-offset is related not to the ADC module but to the NIM bin.

In order to improve these problem, we connected the GND line each other at the monitor-pin of the threshold adjustment of the modules in a NIM bin, so that the GND potential of all modules in the NIM bin would become the same. Table 3 shows the DC offset of each linear-sum output after this modification. Figure 4 shows the distribution of the DC offset of all modules before and after this modification for the comparison. As a result of this modification, the number of positive-offset channels was reduced to 28 out of 83 channels, and extremely-high or extremely-low offset have disappeared. Among these 28 channels, 22 channels that have the offset greater than +3 mV were fed into the the NIM Linear-Sum module and adjusted its offset to zero by the trimmer on the NIM Linear-Sum module which has the adjustable range of

Left rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4	−19	−4	−26	+2	0	−16	−20	−16	−7	−3		
Bin#3	0	+14	+10	+13	−12	+27			−18	−20	−30	−28
Bin#2			−14	−8	+2	−5	−5	+5	+13	+20	+10	+40
Bin#1	+20	+28	+15	+45	+5	+45	−18	−8	−10	−1	−20	−4

Right rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4								−22	−6	+8	+2	−6
Bin#3	−28	−2	−10	+10	−3	+17	−11	−40	−20	−14	−2	+2
Bin#2	−36	−34	−14	−26	−20	−9	−24	+12	−18	+20	+20	+3
Bin#1	−20	−12	−2	−20	−6	0	−14	+17	−18	−12	−10	+18

Table 3: The DC offset (mV) of the linear-sum output after connecting the GND of the circuit-board of the Amp-Discri module each other. Colored value indicates the positive offset. 28 out of 83 channels have the positive offset.

about 0 ± 50 mV just before they were put into the trigger-decision logic.

The trimmer for the DC-offset adjustment is now attached directly on the circuit-board, which is one of the problem to make the adjustment difficult. When we designed the circuit of Amp-Discri module, we never thought that the DC-offset adjustment was so difficult as the current situation. The method of the DC-offset adjustment we thought was as follows. We use the extender-cable to supply the power to Amp-Discri module outside the NIM bin, connect all input cables to the module, open the module-cover to access the trimmer, then adjust the DC offset by looking at the DC offset of the linear-sum output by the oscilloscope. We also thought that we need to do this adjustment only once at the first time when we begin to use this module. However, in reality, The voltage-drop for the 2.6 A of current by the 2 meters of the extender-cable was so large that we could not ignore this drop since the DC offset of the Amp-Discri circuit completely depends on this voltage. This result in the change of the DC offset value of the Amp-Discri module inside and outside the NIM bin, and we had to repeat the adjustment until the offset became zero inside the NIM bin.

The method I used in the final adjustment just before the engineering-run was as follows. I read the DC offset on the oscilloscope, turn off the power of NIM bin and pull out the Amp-Discri module a bit from the NIM slot so that I can access the trimmer on the circuit-board, rotate the trimmer a little bit, return the module to NIM slot, turn on the power of NIM bin and read the offset by the oscilloscope, and repeat this process several times until the offset became zero. It took about 3 hours to adjust 42 of Amp-Discri modules.

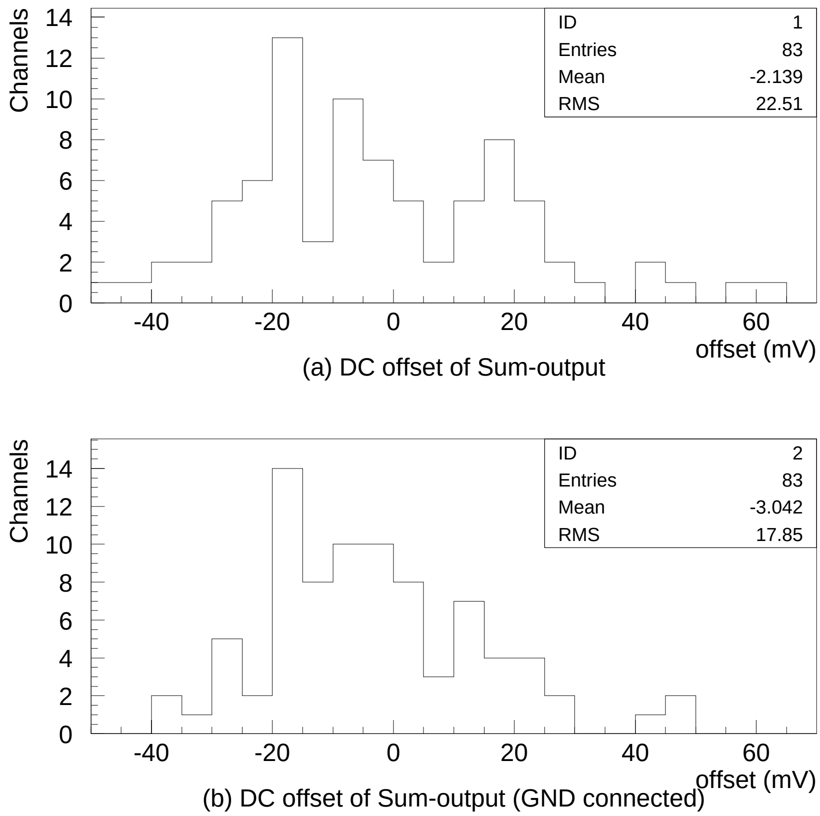

Figure 4: The DC offset distribution of 83 channels of the linear-sum output before (a) and after (b) connecting the GND each other.

6.2 The noise on the linear-sum output

The noise from the signal cable can be measured directly by the oscilloscope or by the width of the pedestal distribution taken with the random trigger.

The noise on the signal cable from the each CsI PMT was measured as less than 1 mV height by the oscilloscope, and the pedestal width is about 1.4 ch of ADC which correspond to about 70 fC of charge. This is small enough for the requirement of the E391a experiment. Figure 5 shows the distribution of the

On the contrary, large AC noise of 50Hz, greater than 10 mV of pulse height, was observed on some of the linear-sum output by the oscilloscope. The pedestal distribution of these channels did not become the Gaussian shape, and the width became around 50 ch of ADC. Some has the double- or triple-peak in its distribution. Figure 6 shows the pedestal width of the linear-sum output. Table 4 shows the location of these Amp-Discri modules.

From the Figure 7 that shows the correlation between the pedestal width

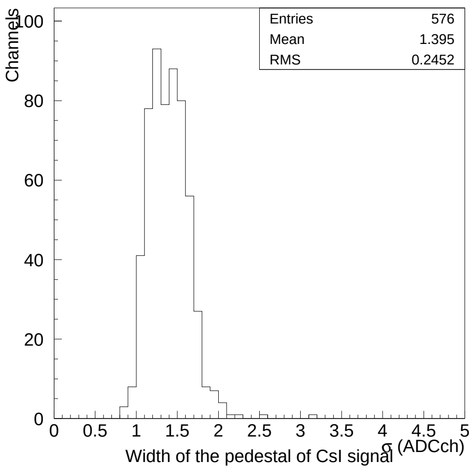

Figure 5: The pedestal width distribution of each PMT signal of the CsI. The $x-$axis is in the unit of ADC ch. 1 ch corresponds to the 50 fC of the integrated charge.

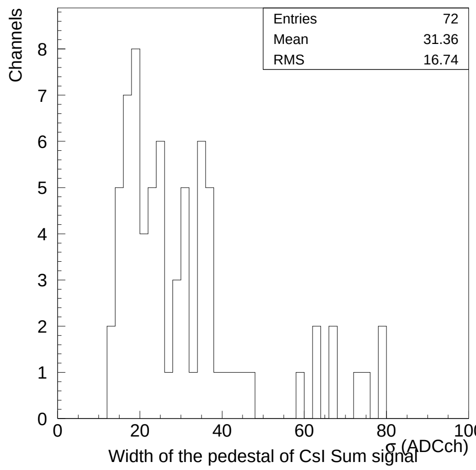

Figure 6: The pedestal width distribution of the linear-sum output of the 8 PMTs signal of the CsI. The $x-$axis is in the unit of ADC ch. 1 ch corresponds to the 50 fC of the integrated charge.

Left rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4							25.8	22.3	21.7	37.2		
Bin#3	45.0	28.8	31.2	36.5	30.4	40.9			30.0	35.0	42.3	31.6
Bin#2			30.9	34.7	28.3	36.0	36.3	33.0	67.6	62.3	47.7	58.3
Bin#1	73.5	67.5	62.2	79.2	78.8	74.1	23.8	19.5	14.3	16.6	15.9	13.3

Right rack	slot 0-1		slot 2-3		slot 4-5		slot 6-7		slot 8-9		slot 10-11	
Bin#4												
Bin#3	26.1	25.0	23.3	29.7	16.7	25.5	18.4	15.6	18.5	16.0	21.0	23.4
Bin#2	18.4	17.0	37.4	35.6	34.6	35.4	38.9	34.4	22.1	24.1	24.1	17.7
Bin#1	24.6	18.4	19.3	19.4	17.4	17.4	21.3	13.4	15.7	14.6	21.0	19.8

Table 4: The pedestal width of the linear-sum output of the Amp-Discri module, in ADC ch. The yellow-colored value indicates the width greater than 30 ch, and the red indicates greater than 50 ch.

of the linear-sum and the ADC module which the cable is connected to, we can judge that the pedestal width of the linear-sum output does not depend on the ADC module.

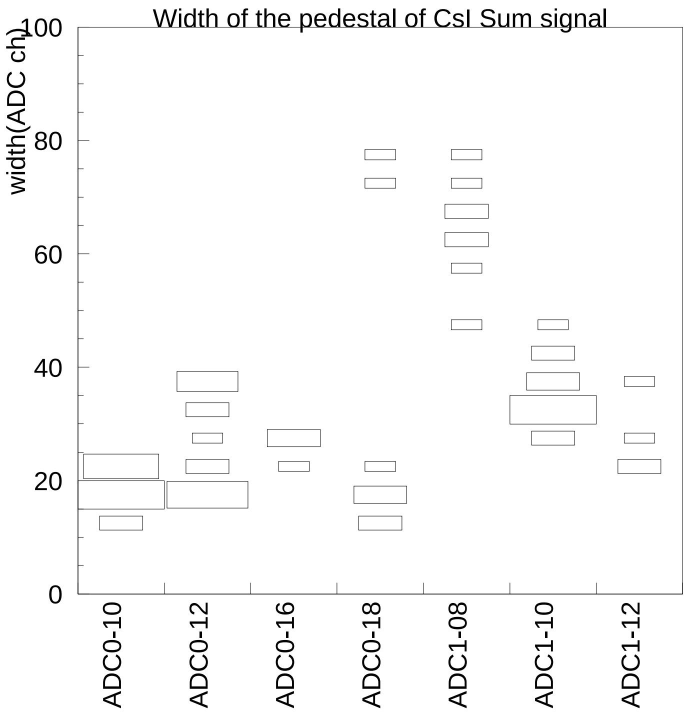

Figure 7: The ADC module dependency of the pedestal width of the 72 channels of linear-sum output.

6.3 NIM Bin's problem

A NIM bin has the capacity to store the 6 Amp-Discri modules in it. However, some NIM bin shows the instability on the power supply to the modules in some slot. As shown in the Table 2, 4 slots among the 8 NIM bins we are using now shows the very-high(low) or unstable GND potential to the Amp-Discri module when we insert it to the slot. The DC offset of the linear-sum in these slot reached around $+300 \sim 500$ mV, which cannot be adjustable even by using the additional NIM Linear-Sum module. For now these slot are left blank, thus we need additional NIM bins when we use full set of the detector channels for the physics run. Due to the limitation of the space around the detector, we do not want to add more NIM bins. The problem will be that most of the NIM bins became old and have some problems in it, and not so many NIM bins can operate with the full capacity. I tried 12 NIM bins but found only 5 bins can operate with 6 Amp-Discri modules.

The power consumption is another problem for the NIM bin. An Amp-Discri module consumes -6 V, 2.6 A of electricity. Even the so-called 'high-power' NIM bin has the capacity of 15 A for the -6 V, which is smaller than the sum of the 6 Amp-Discri modules, 15.6 A. Thus we are operating the NIM bins in a full-spec or rather over-spec for now.

The voltage-drop is also the serious problem. The power of a module is now supplied by one connector per module. If the power-supply line for each slot in the NIM bin is not thick enough, the 2.6 A of current will cause the voltage-drops. The non-zero offset of the GND of each circuit-board might be caused by this voltage-drops. In reality, the maximum current for each slot in the NIM bin seemed to be assumed at around 1 A. The instability of the GND potential of the NIM slot is the serious problem to the Amp-Discri modules since it uses the GND potential as the reference voltage to the DC offset of the linear-sum output.

7 Plan for the possible solution

7.1 The DC offset on the linear-sum output

Following plans will be possible to solve the DC offset problem on the linear-sum output.

- Change the variable range of the DC offset adjustment by replacing the variable- and fixed-resister. Making the range twice as wide as the current setup and shifting the range to the lower offset region such as $+60 \sim -140$ will be enough to solve the problem.
- Make it possible to access to the trimmer from the front panel.

If we are allowed to apply some large modification in the circuit, another possibility will be that

- Give up to use DC coupling to the linear-sum circuit, and change it to the AC coupling. It requires the great change in the linear-sum circuit, but the circuit-board itself cannot be replaced any more. Thus the possible way will be that we attach the additional small circuit-board for the AC-coupling circuit.

7.2 The AC noise on the linear-sum output

As for the AC noise on the linear-sum output, we should continue to investigate the actual cause. The important thing is to understand which part causes this AC noise, Amp-Discri itself, NIM-bin or slot, or other source on the electronics, as early as possible.

7.3 NIM Bin and the power consumption

Following plans will be possible to solve the NIM-bin itself and the power consumption.

- Modify the NIM bin to increase the capacity of -6 V power. Cabling between the regulator and each slot inside the NIM bin might also need to stand with the power. (Though we think the modification of the existing NIM bins would be difficult in reality.)

- Attach the power-supply terminal for each circuit-board to reduce the load for each power-supply line to half. This will reduce the voltage-drop due to the over-current to the power-supply cable. Additional connector will be needed to the back panel of the Amp-Discri module.

- Replace the power-supply module to the NIM bin. Since Amp-Discri module only uses the -6 V and GND, the ordinary DC power-supply regulator is usable for this purpose. Some modification to the cabling inside the NIM bin might be needed.

8 Summary

During the beam time from Oct. 2002 to Dec. 2002, newly developed module 'Amp-Discri' was tested as a first-stage signal-processor in the KEK PS-E391a experiment.

As for the discrimination of the small signal which is the most important role of this module, we achieved to distinguish the 1 mV of the pulse height of the detector signal from the noise, as we expected.

As for the 8-channel linear-sum circuit which is used as the simple hardware clustering and triggering signal, two serious problems have appeared. One is that the DC offset cannot be adjusted to zero, and the other is that the AC noise appears on the linear-sum which leads either to the bad energy resolution or to induce some biases in the triggering. The noise problem appeared only on the linear-sum output but not on each detector signal.

The excess of the power consumption to the capacity of the NIM bin will lead to the instability of the operation of the Amp-Discri modules.

The possible plan to solve the DC offset problem will be that we will modify the variable range of the adjustment, or we will change the circuit from the DC coupling to AC coupling. Either way requires more or less the modification on the circuit, so it will take some time for this modification.

The possible plan to solve the NIM bin problem will be that we will increase the capacity of the power supply and/or the reduction of the load for each power-supply line.

9 Schedule

We will have the test beam with slow-extraction on July 2003. In order to take data during this period, the modification of the Amp-Discri module and related equipments should be finished before that. Considering the period for the adjustment and test of the system including the Amp-Discri module, the method of the modification should be fixed until the end of March, and then the modification itself for all 65 modules should be finished until the end of May.