

Amplifier / Discriminator Card for LUIS and DSC Projects - Principle of Operation

A position measurement of a muon in a proportional tube depends upon the precise determination of the drift time of the first electron. As the electron approaches the sense wire, an avalanche occurs which produces between 10,000 and 100,000 electrons, depending on the gas gain. The gain is a function of the gas mixture and high voltage. The purpose of the amplifier / discriminator card is to further amplify this current pulse and determine if it exceeds a threshold set to correspond to the expected amplitude.

The circuit diagram of one electronics channel is shown in Figure 1. A transimpedance amplifier (AD8015) converts the input current pulse to a low impedance differential output voltage with a voltage gain of about 40. A differential amplifier (AD8132) provides an additional voltage gain of 5, for a total gain of 200. The resulting signal is applied to a comparator (AD96687 with ECL outputs or ADCMP604 with LVDS). If the signal exceeds the threshold voltage applied to the comparator, the output goes true until the signal drops below the threshold. The resulting differential output is sent via twisted pair cable to the appropriate receiver on the time-to-digital converter card. The circuitry has very large overall gain, requiring great care in the layout and shielding to avoid noise pickup or oscillation. The minimum useful threshold is about 25mV for the DSC board and somewhat higher for the LUIS board.

The DSC electronics includes a neutron detection circuit. At the positive going output of each amplifier channel, a low voltage schottky diode is used to conduct signals exceeding the diode's threshold to a summing amplifier followed by a comparator. Large signals on any of the 16 input channels due to neutrons will be detected at this comparator.

The DSC card requires +6 V @ 0.9A total for 16 channels / proportional tubes. A local voltage regulator is used to produce +5 V. The external threshold voltage (~ 10 X actual threshold) is sent to the card and buffered there. The LUIS electronics requires +5 V @ 0.4A and -5.2V @ 0.4A total for 8 channels / tubes. The threshold is set by potentiometer on the card, again to ~ 10 X actual threshold.

Some useful numbers concerning the performance of the Amp / Disc Cards:

1. Sensitivity computed using the approximate voltage gain.

Charge collected for gas gain of 30,000 = 1.6×10^{-19} coulomb/electron * 3×10^4 gain
= 4.8×10^{-15} coulomb

Voltage at circuit input = $Q / C_{\text{tube}} = 4.8 \times 10^{-15}$ coul / 30 pf = 160 μ V

Amplified voltage = 160 μ V * 200 gain = 32 mV

With a threshold of 25 mV, this signal would be sufficient to generate a valid output

2. Sensitivity computed using the transimpedance gain.

Effective discharge time = $T = R * C = 350 \text{ ohm} * 30 \text{ pf} / .65$ (fraction discharged) = 16 ns

Current at circuit input = $I = Q / T = 4.8 \cdot 10^{-15} \text{ coul} / 16 \text{ ns} = 300 \text{ nA}$
 Voltage at output of transimpedance amp = $E = I \cdot R = 300 \text{ nA} \cdot 20000 \text{ ohm} = 6.0 \text{ mV}$
 Amplified voltage = $6.0 \text{ mV} \cdot 5 \text{ gain} = 30 \text{ mV}$
 Equivalent to result from #1, shown above.

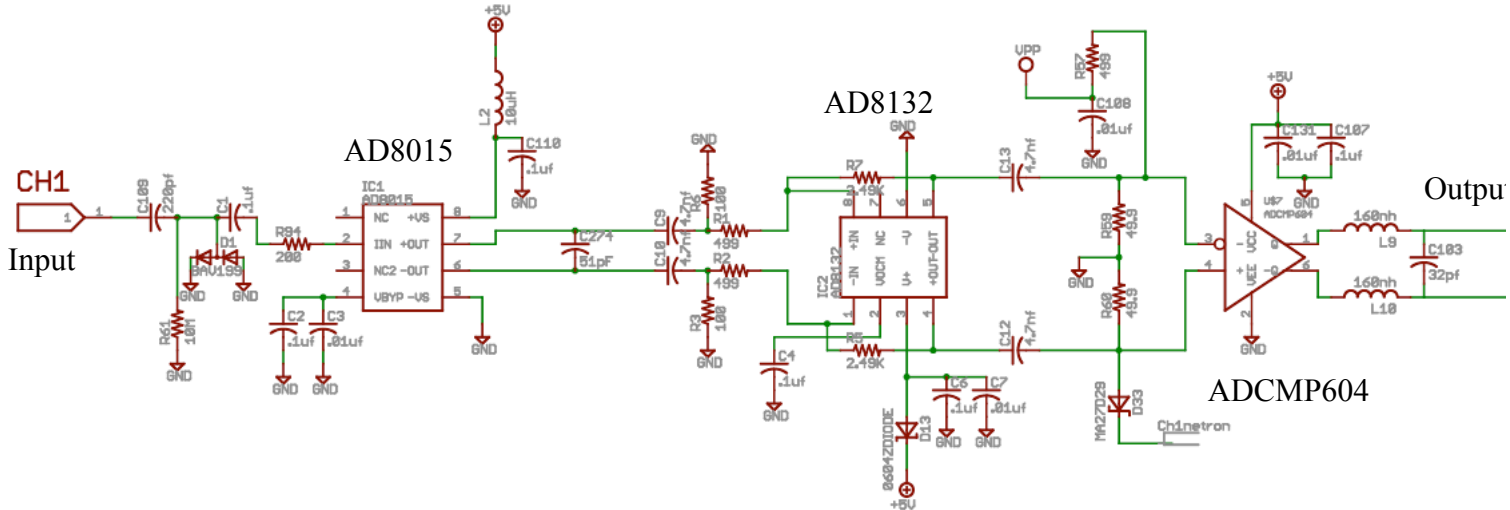


Figure 1. Circuitry for one channel of the DSC amplifier discriminator card. The LUIS card is similar, with an ECL output comparator instead of the LVDS device shown here. High voltage is distributed to each input on the LUIS card but is done on a separate card for the DSC system. V_{pp} is the threshold voltage supply.

Notes on circuit design:

1. Protection diodes are placed at each input to prevent sparks / discharges from damaging the transimpedance amplifier inputs.
2. The 200 ohm input resistor sets the input impedance to about 350 ohms.
3. Extensive decoupling is used at all power supply pins and on the threshold circuitry to prevent crosstalk and noise pickup.
4. Each amplifier and comparator is low-pass filtered at ~60 MHz to minimize pickup of VHF signals and to prevent feedback.
5. Supply voltage on each AD8132 amplifier is set to 2.7 V (using a zener diode) to limit signal amplitudes at the comparator to a safe level.
6. Low impedance differential signals and terminations are used for all signals to minimize signal pickup and radiation.
7. The neutron pickoff diodes are special schottky (MA27D29) devices with very low forward voltages.
8. Capacitive coupling is used between all stages to remove DC offsets.
9. Output traces are on an inner, shielded board layer. 50 ohm microstrip lines are used for all long signal traces.
10. High voltage areas on the LUIS board are corona-doped to prevent breakdown to neighboring components. Corona dope is not needed on the DSC board.