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Details of the Active Splitter Utilized in the L2 Upgrade

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Abstract

This note contains details on the design and implementation of an active optical signal splitter employed in the L2 upgrade. This active splitter drives two copies of the input optical signal at zero loss to the Run 2A and 2B L2 interface boards; specifically these splitters are used to split the 48 signals lines coming into L2 from the ShowerMax subsystem. The splitter circuit, the board design and the crate in they are housed, along with power and fusing issues are discussed within.

1 Introduction

The commissioning strategy for the L2 upgrade relies on parasitic spying on the L2 inputs to the Run 2A system. Parasitic spying on the data will be accomplished by splitting each input channel into two copies, one feeding the Run 2A L2 system, the other feeding the upgrade electronics. The present L2 system has inputs from six different data sources, with nearly each input path employing a different technology in the delivery of data into the trigger system. The variety of types of input signals complicates the task of splitting the incoming data for commissioning of the upgrade.

One of the critical input paths to L2 is that of the ShowerMax information, which aids in electron identification and rejection of fake EM clusters. There is a ShowerMax subdetector in

Wavelength	820 nm
Data Rate	20 MBd
Fiber Size	62.5 um/125 um
Connector	ST

Table 1: A few specifications of the TAXI+HFBR optical link employed in the transmission of ShowerMax data into L2.

each of the 48 wedges of the EM calorimetry; each ShowerMax wedge transmits trigger data from an SMXR board [1] into L2 over an optical link governed by the TAXI protocol [2] and transmitted using Agilent HFBR series optical components [3]. A few important characteristics of this link are listed in Table 1.

At the time of the SMXR design, these optical components were state-of-the-art and remain today a relatively inexpensive choice for building optical links. We see however from Table 2 that there is a wide spectrum of optical transmission power in the 48 channels presently employed in the system.

After extensive bench testing using real upgrade electronics, optical splitters from NetOptics [4] were chosen for use in splitting the ShowerMax optical channels. A typical optical splitter like the NetOptics product described above has one input and two outputs; the output optical signals however cannot accurately be called *copies* though because the output signals are driven at an optical transmission strength that is one-half of the input signal. This loss can be quantified this way:

$$Loss = L = 10. * log_{10} \frac{P}{P_{ref}} \tag{1}$$

in units of dBm. If P_{ref} is the optical power of the input signal, and P is that of the split-in-half output signal, then $P/P_{ref} = 0.5$ and

	Loss (dBm)			
Channel Number (N)	East N	East N+12	West N	West N+12
0	-15.20	-15.50	-15.91	-15.56
1	-16.94(*)	-16.86(*)	-17.01(*)	-15.47
2	-17.74(*)	-19.41(*)	-17.01(*)	-15.73
3	-14.67	-16.00	-16.44	-15.47
4	-19.15(*)	-15.12	-17.62(*)	-18.35(*)
5	-13.22	-17.07(*)	-18.82(*)	-15.52
6	-17.45(*)	-17.21(*)	-16.55(*)	-19.30(*)
7	-15.33	-15.69	-19.07(*)	-15.68
8	-16.42	-18.29(*)	-17.90(*)	-14.66
9	-15.08	-15.82	-16.15	-15.27
10	-17.20(*)	-16.53(*)	-18.20(*)	-17.22(*)
11	-17.89(*)	-17.20(*)	-18.40(*)	-15.80

Table 2: Optical signal transmitter strength for the 48 CES channels. Larger negative values indicate weaker transmission channels.

$$L \ - 3.0dBm \tag{2}$$

Such an optical splitter is called *passive* because its outputs are not driven; the outputs signals are produced by splitting the incoming light using some sort of prism.

Add this light loss from the splitter to the broad spectrum of optical transmission strengths in the system and problems arise. Incurring an additional -3.0 dBm loss pushed some of the weaker channels beyond the minimal input power required on the *receiver* end to achieve a stable optical link. It was determined that channels with a prior-to-splitting optical transmission strength less than -16.5 dBm were susceptible to errors on the receiver side if passive splitting were employed. This amounts to about 50% of the ShowerMax channels.

We should note here what the optical link used in the system is really doing. There is some digital logic on the SMXR board that forms a 32-bit trigger word, which is transmitted via an electrical signal (ECL) to the TAXI encoder chip on the SMXR. This chip codes the 32-bit word into something TAXI-specific, meaning that the 32 bits of data are arranged in some bit-framing that is used by a downstream TAXI interpreter to decode the information. The resulting analog signal is then input to the Agilent HFBR optical transmitter, which is at its core a light-emitting diode(LED). This light is sent along optical fiber to the receiver end. The optical signal is collected in the receiver (a photodiode) and converted into an analog voltage, which is subsequently sent along to the corresponding TAXI interpreter where the 32-bit data word is unpacked and sent along its merry way in ECL.

One should note that the optical strength of the light coming out of the transmitter LED is determined by the input current, so the TAXI bit-framing and arrangement must be somewhat culpable in the spectrum of transmission strengths. Some responsibility should also be heaped upon the Agilent parts; a study of several Agilent transmitters not driven with the TAXI protocol indicate a -2dBm spread of transmission strengths under these circumstances as well.

The problem of the weak transmission strength manifests itself in smaller amplitude ECL signals at the receiver end, and it is the inability of the TAXI protocol to interpret these reduced amplitude signals that makes using passive splitters inadvisable in the commissioning of the L2 upgrade.

We have designed an alternative to the passive NetOptics splitter, an active or driven optical signal splitter that transmits light without loss with respect to its input optical power. The active splitter circuit is simple but performs it task. The circuit design is discussed in Section 2. Active splitter boards containing several of these simple circuits were built at Penn for use in the L2 upgrade commissioning; these boards are discussed in Section 3. Finally Section 4 contains a barrage of potentially useful nuggets of information on the active splitter implementation.

2 The Active Optical Splitter Circuit

The task of actively splitting the optical signals is performed by a relatively simple circuit [5]. An Agilent optical receiver (HFBR-2416T, the same optical receiver employed on the Pulsar TAXI receiver mezzanine cards) receives the optical signals and converts them into an analog voltage. The analog signal is then AC coupled to the non-inverting input of an ECL comparator (AD96687 an Analog Devices part [6] that actually contains two comparators. The two halves of the single ceramic part are used in two separate active splitter circuits. See the schematic for details.) The inverting input of the comparator serves as the reference voltage and is set by a variable resistor.

The function of the comparator is to discriminate the analog signal from the optical receiver. The comparator takes the signal and compares it to a small DC offset voltage (normally about 20 mV) and sends out an ECL level to the optical drivers. Note that the reference voltage on all active splitter circuits has been set to 20-22mV.

The inverted ECL output of the comparator is then fed to the four inputs of a Motorola quad-line receiver, MC10H115 [7]. Each of the 4 input channels is a differential signal amplifier; four output signals are then amplified copies of the input signal. Two of the four output signals are used to drive optical transmitters, Agilent HFBR-1414T.

The circuit requires +5 and -5V. The power draw is much larger on the -5V supply than the +5V. Board-wise power consumption will be discussed in Section **??**.

The output signal strength is determined by the current through the optical transmitter. This current is determined by a limiting resistor connected to pin 3 of the optical transmitter. Early versions of this active splitter circuit were pumping light out at nearly 4 times the transmission strength of other optical transmitters used in the system. Although this optical power is still within the specification of the Agilent optical receiver and TAXI interpreter, we opted to increase the value of the pull-up resistor on the transmitter side (from 30Ω to 60Ω) to thereby decrease the current driving the LED within the transmitter and thus throttle back the optical power on the output signal.

3 The Active Optical Splitter Board and Crate

The active splitters for the L2 upgrade have been built by hand at Penn. The circuits are laid out on Vector boards [8], which are place-and-connect component boards. The virtue of the Vector board design is that one can exploit the available ground plane on one side of the board and ground frame around the placement field. Four active splitter circuits are laid out on each vector board, the dimensions of which are given in Table 3.

The receiving and transmitting optical components are all on one side of the board, making it easy for inserting or removing fibers. Two colored LEDs on each board indicate the presence of +/-5V power. Red indicates +5V and green indicates -5V. The supply voltages are separately fused on the board.

Each board, containing four active splitter circuits draws 700 mA on the -5V supply and 40 mA on the +5V. Per board fusing must accommodate the appropriate currents: we use a 1A fuse for the -5V supply and a 0.5A fuse for the positive supply. We of course could have used a smaller fuse on the positive supply, but 0.5A fuses are pretty common and we utilized a convenient value.

The active splitter boards reside in a custom made crate in rack 2RR31C. Table 3 has some pertinent information. This crate is capable of powering 15 cards simultaneously.

The crate is powered using 2 Lambda JWS100 supplies, which convert standard AC input to a 5V - 20A max output. The +5V and -5V are provided by tying the negative output terminal of one supply to the positive terminal of the second supply. The remaining output terminals are at +/-5V. Power to the crate is monitored in the CDF monitoring system [?]. AC comes in through a single heavy gauge standard AC cord plugged into an outlet near the rear of the

Length	7.5 in
Width	19 in
Height	7.875 in
Number of slots	15
Slot spacing	1.4 in
Per-board dimensions	4in x 6in
+5V power (1 boards)	40mA
(12 boards)	480mA
(15 boards)	600mA
-5V power (1 boards)	700mA
(12 boards)	8.4A
(15 boards)	10.5A

Table 3: Some details regarding the optical splitter crate.

Length	3.75 in
Width	8 in
Height	2 in
Output voltage	5V
Max current	20A

Table 4: Some details regarding the Lambda JWS100 +5V and -5V supplies.

rack. Crate power is governed by a single switch on the rear of the crate, which has an LED indicator light that illuminates when AC is reaching the power supplies.

Power is distributed to each of the fifteen slots via heavy gauge copper wire for each of the supply voltages to a series of fifteen backplane connectors. Each active splitter has a 96 pin connector that fits into the backplane slots for power. Only 18 of the 96 pins are utilized, six each for +5V, -5V and ground, which is shared between the power supplies and distributed in a similar manner.

Each power supply is also fused at a level to accommodate a full complement of active splitter boards. The +5V supply is fused at 12A and the -5V is fused at 1A. Combined with the board fusing and AC supply fusing, this redundant internal power supply fusing is used to minimize the risk to other CDF electronics.

The active splitter crate is a completely self-contained apparatus. AC power comes in, along with input optical fibers; 96 fibers go out.

4 General Information and Instructions

Some general information - this section will evolve as needed.

4.1 Fusing

Each active splitter board has two fuses, one for each supply voltage. These fuses have wire leads and are inserted in sockets on the board. The 4-circuit splitter board draws 700mA on the -5V supply, so we use a 1A fuse for -5V. The splitter draws a much smaller amount of current from the +5V supply - just 40mA - so the fusing can be smaller. We use 0.5A fuses for the positive supply because this is what was available. Clearly we could use anything as small as a 50mA fuse.

A small amount of these wire fuses can be borrowed from Roberto's stash on the first floor of B0. There is a blue multi-compartment drawer with small component supplies in the corner of the workspace under the long-term storage area. Inside the drawers one can find a small number of these fuses in a pinch. We will order our own supply of fuses for our boards.

The active splitter crate is also fused. These fuses are cylindrical glass structures that insert into metal end caps. Take care in removing or inserting the glass fuses in the end caps, for the fuses are somewhat fragile. The crate is fused such that a fully filled crate can still be driven. Given that the crate can accommodate 15 boards, the max current drawn from the crates supplies is:

$$\begin{aligned}
\text{-5V:}\quad & 700\frac{mA}{\text{board}} * 15 \quad \text{boards} &= 10.5A \\
\text{+5V:}\quad & 40\frac{mA}{\text{board}} * 15 \quad \text{boards} &= 600mA
\end{aligned}$$

We therefore fuse the -5V supply at 12A and the +5V at 1A. These fuses can be found in the same general location in the electronics work area on the first floor of B0. The fuses are located on the rear face of the splitter crate; they are removed by unscrewing the black fuse holder and removing the fuse.

Board-level power is indicated by 2 LEDs: red is for +5V and green is for -5V. The integrity of the crate power supplies is monitored by the standard power supply monitoring in CDF. One can easily tell if the crate is receiving power by looking for the power light near the rear AC switch.

4.2 Spare Power Supplies

The +5V and -5V supplies are identical Lambda JWS100 modules. A single spare power supply has been supplied. This spare power supply has been tagged and is stored in the standard spare power supply cabinet on the first floor of B0. The tag reads "L2 ShowerMax Active Splitter Crate Spare Power Supply: +/-5V 20A"

4.3 VLTN Testing

The TAXI protocol is a method of encoding the bit information coming from upstream logic elements in preparation for transmitting the data over an optical link. The TAXI protocol takes an ECL input signal and then frames the incoming bits in a pattern - 4b/5b, meaning four bits of digital data are encoded in five bits of sent optical data - that corresponding downstream

TAXI interpreters can understand. As long as clocking is being received, the TAXI link is always working, regardless of whether real or useful bit packets are being fed into it. So even if no real data is input to the TAXI encoder, the TAXI frames are still sent forward to the optical portion of the link and empty frames are transmitted.

The TAXI protocol is nice in that it has a built-in failsafe mechanism that checks the integrity of the optical link. This mechanism relies on the ever-present TAXI bit-framing structures to be present - without regard for the bit content. If the TAXI interpreter on the receiving end fails to pick up the framing when it is expected, an error line (VLTN) goes high.

We rely on this TAXI link integrity check in the checkout of the active splitter boards. This test is convenient in that it does not require a CDF VIPA crate or CPU, or really any significant system infrastructure for that matter. All the hardware that is needed is a transmitter-receiver Pulsar TAXI mezzanine card pair and the active splitter.

The mezzanine cards require 5V power; each card draws about 1.3A, so one must use a supply that provides that minimal requirement. Power can be brought in in a variety of ways; the easiest and recommended way is to place the mezzanine cards component side down and solder 0.5in pins in the VCC and GND vias on each board facing up. The spacing of the power and ground vias near the corners of each card are just right to accommodate the three-pin connectors available from the electronics technicians here at CDF. George Wyatt has a stash of these 3-pin connectors with leads already made - they are located on the ground floor of B0 in the tech area near where Lew Ford sits. There is a large center bench under which there are many drawers where these types of parts can be found.

The mezzanine cards have jumpers on them that force the card to either pay attention to the global CDF clock it receives from its connection to the CDF DAQ, or to get its clocking from the local clock, provided by an onboard 12MHz oscillator. For the VLTN test we use the local clocking, so make sure the jumpers are set on the two left pins (looking at the no-component side of the mezzanine card, with the optical parts on your right).

The active splitter cards do not need the crate for these tests. George Wyatt provided us with two 5V MIL power supplies which have sufficient current to power a single active splitter board. These 2 MIL supplies are hard-wired to a standalone 96-pin backplane connector into which we can insert active splitter cards one at a time. This is sufficient for the VLTN tests we seek to perform.

Once powered and with proper jumper settings for the clocking on the mezzanine cards, one can connect an optical fiber from the transmitter into the receiver on the active splitter. One of the corresponding transmitter channels can then be connected to a channel on the Pulsar receiver mezzanine card. The VLTN line is mapped to one of the debug lines on the Pulsar TAXI receiver mezzanine cards for easy probing (pin 16).

A scope can then be used to watch for the VLTN signal. VLTN is held logic-low during normal operation; VLTN goes high when a transmission error is encountered by the TAXI receiver on the mezzanine card. VLTN returns to logic-low state when the next valid frame is detected. The framing of empty data comes through the link at 80MHz; this high data transmission frequency allows one to perform high-statistics testing of the integrity of the optical link in a short amount of time.

Each active splitter card has gone through VLTN testing as part of the board checkout procedure on each of the 8 output channels. Each channel was tested for at least one hour of running, which constitutes a check of nearly 3E11 frames. This level of testing is not possible with driven patterns in a Pulsar transmitter-receiver setup given the much smaller data frequency and overhead induced by readout on the receiver end. Of the 14 cards that were assembled only 3 of the 56 channels have been identified with problems. These problems will be diagnosed and repaired either here at FNAL or back at Penn.

4.4 Probe Points and Signal Behavior

This section will ultimately contain also contain scope pictures of the waveforms at the given probe points.

5 Summary

We have designed and built an active optical splitter to be used in the commissioning of the L2 upgrade. This splitter is intended to be used to split the 48 channels of ShowerMax data that come into L2 - and is necessary because of the large fraction of ShowerMax channels that are too weak to split by conventional passive devices. The active splitter boards are used in the system to drive signals into both the Run 2A and 2B L2 systems.

References

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[5] The schematics can be found at http://hep.upenn.edu/xxxx.html

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[9] Information on CDF power supply monitoring can be found at http://www-cdfonline.fnal.gov/mcs/cdf5749_PSM_Alarms.pdf