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PULSE HEIGHT ANALYZER/OSCILLOSCOPE DISPLAY INTERFACE

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ABSTRACT

A portable interfacing instrument was developed that accepts digital information from a pulse height analyzer and displays it as an energy spectrum on an ordinary laboratory oscilloscope.

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A PULSE HEIGHT ANALYZER/OSCILLOSCOPE DISPLAY INTERFACE

INTRODUCTION

A 4096-channel Pulse Height Analyzer (PHA) and a Micropro-
cessor-based Controller were developed at the Savannah River
Laboratory.[1,2] An energy spectrum stored in a memory array in
the PHA may be read out as 4096 binary words, each 20 bits long.
All or part of this spectrum would best be displayed in graphic
form as discrete energy levels on the horizontal axis versus
total number of events at each level on the vertical axis.
Ordinary laboratory oscilloscopes are available for this type
display, therefore an instrument was developed to convert the
digital PHA data to the required oscilloscope input signals.

Initial design requirements were:

1. The device must be portable, and therefore light weight, a
   convenient size, and battery-operated. (rechargeable
   batteries would be preferred.)

2. Vertical display must be linear, the analog equivalent of 10
   successive binary bits, and range selectable from the 10 least
   significant through the 10 most significant bits in 6 steps.

3. Horizontal display must be linear, include 4096 channels (or
   less, as desired), and be a function of the timed sweep of
   the oscilloscope.

COMPONENT SELECTION

The design requirements dictated the choice of most of the
system components. Some are listed below:

1. COS/MOS (Complimentary-symmetry, metal-oxide semiconductor)
   logic for its low power consumption.

2. Sealed lead-acid, gelled-electrolyte batteries for their
   capacity, charge-discharge characteristics, and convenient
   voltage ratings.

3. Wire-wrapped logic boards for their ease of plugging in dual
   in-line packaged (DIP) chips, headers, and extra-board ribbon
   cable connectors.

4. An aluminum attache-sized case for its ease of handling, light weight, and durability.

The choice of COS/MOS logic influenced the selection of the Digital-to-Analog Converter (DAC). In addition to COS/MOS compatibility, the DAC must have good resolution and linearity plus a settling time fast enough to convert 4096 data words in a single oscilloscope sweep where the sweep repeats rapidly enough to provide a flicker-free display. Analog Devices' model AD 7520 meets these requirements, will operate from a single 5 to 15 v power supply and dissipates only 20 MW or power. Output is derived from a separate reference voltage divided via a switched R-2R ladder network. The DAC is a 10-bit unit, of which the least significant bit represents less than 0.1% of full scale. Therefore, readability on an oscilloscope screen will not suffer even when the 10 bits converted are the most significant of the 20 available for display.

PULSE HEIGHT ANALYZER MEMORY ACCESS

The PHA memory is arranged so the 4096 locations, or addresses can be accessed serially when using the "DISPLAY" operating mode. A train of 4096 evenly-spaced pulses may be fed to an address scaler to generate 4096 12-bit addresses. These are applied sequentially to the 20 memory chips (4096 × 1 bit each), each of which goes to a readout buffer. The square-wave pulse train causes the address scaler to advance on each rising edge. New data is latched into the buffers approximately 1 μsec after each falling edge. Thus, 4096 words are presented serially at the buffer outputs (20 lines), each word a 20-bit binary number.

HORIZONTAL DISPLAY

A 250 KHZ clock frequency was chosen to operate the readout logic because of the 1 μsec data switching time of the memory, the 500 nsec settling time of the DAC, and the sweep time of approximately 16 msec for 4096 channels. This requires a sweep repetition rate of a little less than 60 Hz, which yields a flicker-free oscilloscope trace. The 250 KHz pulse train is easily obtained by counting down from the 4 MHz clock frequency in the PHA, and is presented to the interface as a square wave between high and low logic levels - a continuous train of pulses 2 μsec wide and 2 μsec apart.

The portion of the instrument panel (Fig. 1) marked "SCOPE DISPLAY" contains the mode switch and two 4-decade digital thumb-wheel switches (Fig. 2). On the panel, the mode switch is marked "HORIZONTAL." When in the "SET UP" position, the mode

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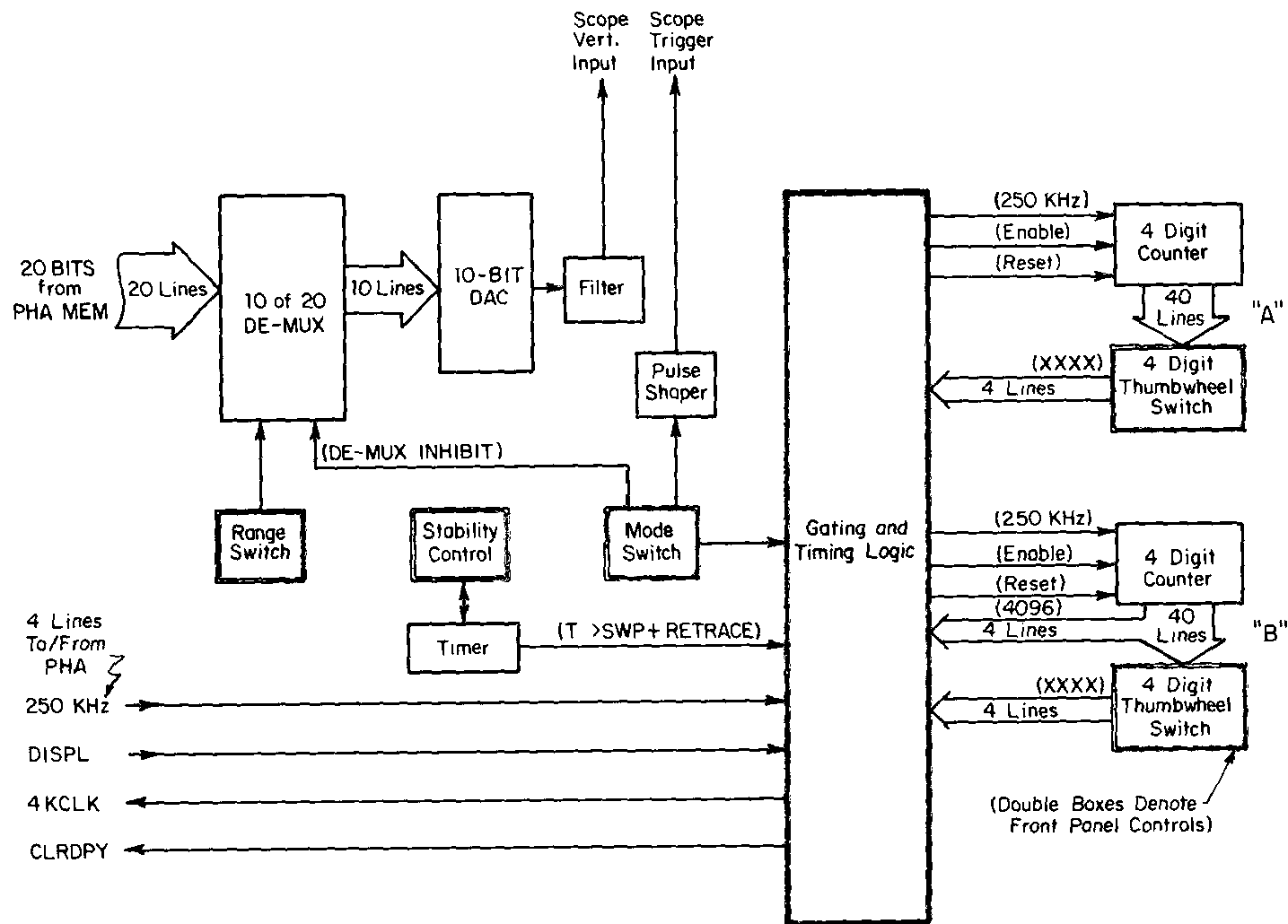FIGURE 1. Instrument Front Panel

FIGURE 2. PHA/Oscilloscope Interface, Simplified Block Diagram

switch selects gating and timing logic to enable a 4-digit
counter ("B") to count the 250 KHz clock pulses until 4096
have been registered, at which time the counter is disabled.
4096 pulses are gated out (4KCLK) to the PHA and the scope
vertical input simultaneously. The scope sweep is triggered
at the beginning of 4KCLK. The operator may use this display
to adjust the scope's sweep controls so that the 4096 pulses
just fill the desired portion of the screen. A timer in the
interface is started when the scope is triggered, and the
time may be adjusted to allow for full sweep and retrace,
after which the process is repeated. The timer adjustment is
marked "STABILITY," and is used to eliminate display flicker.
The PHA address scaler is reset after the 4096th pulse via
the clear display (CLRDPY) line; counter "B" is reset at the
same time.

The same gating/timing action takes place when the mode
switch is in the "4096 CHANNELS" position, except that the
scope vertical input is connected to the analog output of the
DAC instead of 4KCLK.

Positions 3 and 4 of the mode switch bring the digital thumb-
wheel switches into play. Panel markings read "INTENSIFY (or
EXPAND) XXXX CHANNELS STARTING WITH CHANNEL NO. XXXX, where
XXXX is a 4-digit decimal number set up on the thumb-wheels
by the operator. The "INTENSIFY" position allows display of
all 4096 channels (sweep triggered as before), but the
demultiplexer outputs are inhibited for portions of alternate
sweeps. On odd-numbered sweeps analog output is zero from
channel "0" through the number set up for counter "B", normal
for XXXX (B) through [XXXX (b) + XXXX (A)], then zero again
through channel 4095. On even-numbered sweeps analog output
is normal from 0 through 4095. The display intensity may be
adjusted so that a difference in intensity and flicker is
noticeable between the region of interest and the remainder
of the sweep. This allows the operator to locate a peak in
the spectrum by using the thumbwheel switches. The sweep may
be calibrated in terms of energy for further peak identification.

In the "EXPAND" mode the sweep is triggered at the beginning
of the region of interest (XXXX for counter "B"), and the sweep
speed may be increased to expand that portion of the spectrum
as desired.

VERTICAL DISPLAY

The range switch shown in Figure 2 is marked "VERTICAL" (see
Figure 1) and has 8 positions. This switch sends binary-coded
control information to 10 one-of-eight demultiplexers (DEMUX)
as shown in Figure 3. The first two inputs to the 10 DEMUX chips

FIGURE 3. Demultiplexer-DAC, Simplified Diagram

are connected to logic low and high, respectively. The first two
range positions ("CAL: ZERO, FULL SCALE") connect the 10 DAC
inputs to these for calibration; i.e., all bits low yield zero
analog output and all bits high yield full scale output. The
scope vertical gain may be adjusted as desired using these ex-
tremes for reference.

The remaining switch positions connect the DAC (via the
DEMUXs) to 10 data input bits at a time DI_0 through DI_9, DI_2
thru DI_{11}, ----DI_{10} thru DI_{19}) in 6 steps. Switch positions
are marked "COUNTS FULL SCALE: 1K, 4K, ----10^6." It should be
noted that counts in excess of full scale may appear on screen
as a split image. Adjusting the range switch will correct this
if the total does not exceed the maximum range.

BATTERIES

An instrument was also designed for recharging the interface
unit's batteries (Figure 4). Charging is accomplished by feeding
a constant current of 150 ma to the batteries until their series
voltage reaches 14.4 v, then switching to constant mA to the
batteries and an indicator diode in parallel. As battery charge
increases the float voltage of 13.2 is reached and maintained
indefinitely.

The power switch (Fig. 1) has 4 positions: "OFF," where
batteries and external source are disconnected; "INT. BATT.,"
where only the batteries are connected to the load; "EXT. CHG.,"
where batteries and load are connected to the external charging
source; and "CHG. ONLY," where the load is disconnected but the
battery is connected to the charging source. A small light-emit-
ting diode indicates when the external charger is supplying
current, and a meter indicates battery terminal voltage in all
but the "OFF" switch positions. An auxiliary switch disconnects
the batteries when the instrument case is closed to prevent
inadvertent discharge.

The two 6-v batteries are series connected, and are easily
accessible behind a removable cover on the panel.

PERFORMANCE OF THE INTERFACE DEVICE

The prototype PHA/oscilloscope interface has been operated
at SRL in laboratory and field service for approximately one year.
Although operation has been satisfactory, it has been noted that
switching noise in the DAC's analog output creates a background
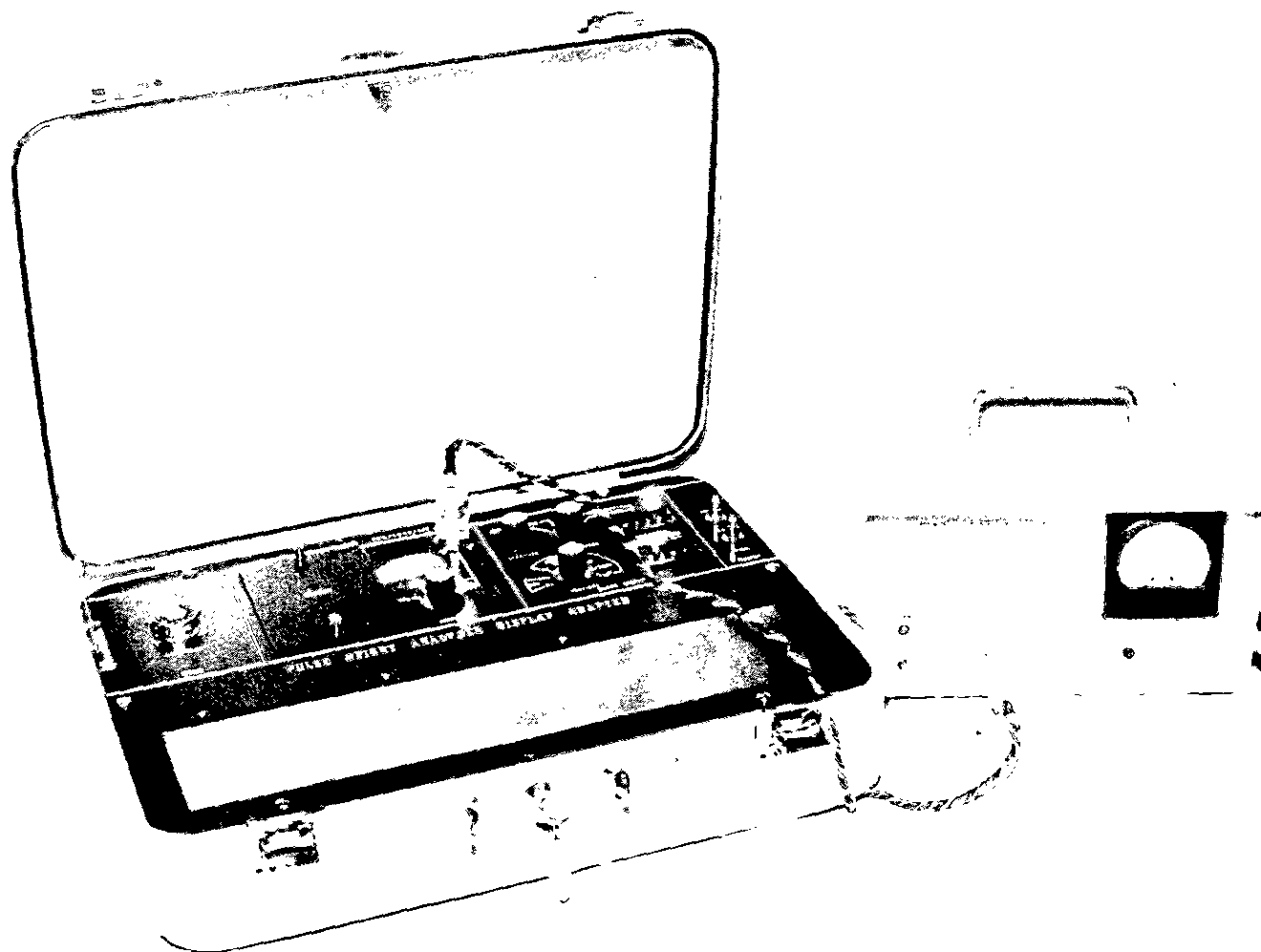glow on the oscilloscope screen at normal brightness settings.

FIGURE 4. Instrument with Battery Charger Connected

This glow appears as a band about the viewed spectrum, the width of which depends on scope vertical gain and interface range settings. The background band does not diminish effectiveness or readability of the display; however, future models will be designed to eliminate this noise.

Also, when the displayed spectrum represents near zero on the vertical axis, the "INTENSITY" mode of operation loses its effectiveness because alternate sweeps cover essentially the same trace. This does not present a problem because that mode of operation is not normally used except when it is desired to locate one region of interest amid other data-containing channels.

The instrument has been used with Phillips, Telequipment, and Tektronix oscilloscopes. Its operation has been trouble-free.

REFERENCES

1. J. S. Byrd and M. H. Goosey, "A Pulse Height Analyzer with Automatic Deadtime Correction." *Nuclear Instruments and Methods,* to be published.

2. J. S. Byrd, "A Microprocessor-based Controller for Nuclear Instruments." *IEEE Transaction on Nuclear Science,* Oct. 1978.