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NOVEMBER 1989

**BATTERY DRIVEN PULSE HEIGHT ANALYZER
WITH 8-CHANNEL SINGLE-GAMMA-PEAK DISPLAY**

T.C. Piper
J.P. Morgan

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IDAHO NATIONAL ENGINEERING LABORATORY

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Westinghouse Idaho Nuclear Company, Inc.
Idaho Falls, Idaho 83403

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ACKNOWLEDGEMENTS

The authors wish to thank Kevin J. Haskell for his significant contribution to the project including, wire wrapping the main board, assembly, troubleshooting and generation of formal schematics.

ABSTRACT

A portable, battery driven, 8-channel pulse height analyzer was designed, built and adjusted to display the characteristic 185 keV gamma of U-235. The system consists of a back-pack, battery/electronics, portion and a hand-held, sensor/display, portion.

SUMMARY

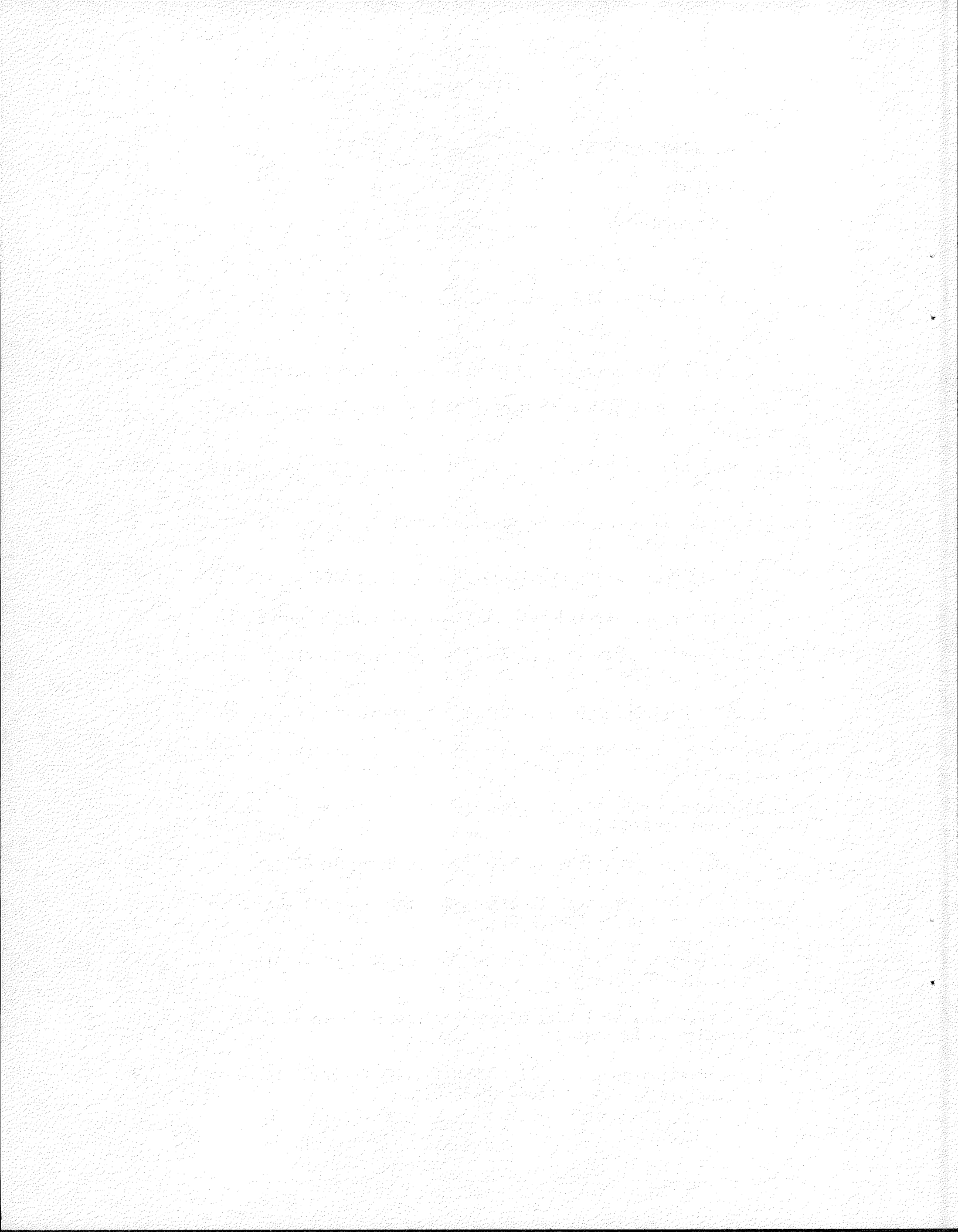
The design and construction details are given for a portable, battery driven, 8-channel pulse height analyzer. The unit that has been constructed consists of back-pack and hand-held sections. Batteries and most circuitry reside in the back-pack portion while the hand-held "wand" contains the 2" diameter NaI detector with photomultiplier tube as well as the system display (an 8 wide x 32 height l.e.d. matrix). System amplification and conversion width was selected to display the outline of the system's resolution of the 185 keV characteristic gamma emitted by U-235. Slight circuitry modifications would allow the display of any other single gamma peak from 60 keV to 2 MeV.

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1. Introduction

A battery operated, eight-channel, pulse height analyzer (PHA) was developed to indicate the presence of U-235 by displaying the prominent 185 keV gamma line of that element. The purpose of this report is to report as well as document the design of this device. Figures 1 and 2 respectively show the interior and exterior of the two "component" system. The heavier, back-pack, portion of the system contains the batteries and the majority of the electronics. The second, hand-held, portion of the system consists of the NaI detector and photomultiplier with attached 8 channel x 32 high l.e.d. (light emitting diode) PHA display. The display also has seven control push-buttons: 4 sensitivity selections and start, stop and reset. More than three hours operation are obtained from fully charged batteries.

2. General Description

Pulse height analyzers present a display of pulse-height frequency-of-occurrence versus pulse height. This is achieved by dividing the possible pulse height range into several, equal, height-segments; assigning a counter to each equal height segment; analyzing the height of each incoming pulse; and adding a count to the appropriate counter. As more and more pulses are analyzed, the pulse height frequency versus pulse-height information develops within the set of counters. Display of the pulse height information can be done concurrently with data accumulation. The content of the several counters is interrogated and plotted vertically against counter identity (ie, pulse height) horizontally.

This simple explanation is exactly the way the present eight channel PHA works. For modern 1024, 2048, 4096 etc. channel laboratory type PHA's, a computer is used and various memory locations are used for count tallying rather than separate several-bit binary counters. For display, the eight channel unit described uses an array of light emitting diodes 8 wide by 32 high whereas the typical laboratory 1024 channel PHA uses a cathode ray tube (CRT). The low height (thickness) of the l.e.d. display compared to a CRT permits the 8 channel display to be mounted on the side of the NaI photomultiplier gamma sensor for convenient viewing as the NaI sensor is directed toward potential U-235 sites.

3. System Operation

Two twelve volt, rechargeable, batteries provide raw ± 12 volt power to three dc/dc converters giving regulated +5, +15 and +980 volt outputs to the electronics and the photomultiplier tube respectively. Figure 3 is a pictorial showing the basic way the

pulse signals from the NaI photomultiplier tube are routed, processed and finally accumulated in eight 12-bit-binary counter "memories". Electrical pulses are generated by the NaI photomultiplier tube (ie, gammas enter the NaI crystal and generating light pulses "viewed" by the photomultiplier tube). These signal pulses pass through a cable to the back-pack unit and are amplified by a Tennelec TC-145 preamplifier and passed to the main wire-wrap board circuitry where they are amplified a bit more and peak detected. Finally, an ADC (analog to digital converter) changes the peak analog height to digital format. If the pulse analog amplitude lies outside the LLD (lower level discriminator) and the ULD (upper level discriminator) span it is discarded without A to D conversion. Pulses within the LLD/ULD range are converted by the ADC and discarded unless the digital format shows they lie within the eight channel display range of interest. A three-to-eight line decoder (74LS138) connected to the appropriate three binary output lines of the ADC along with appropriate timing-logic routes an incremental count to the correct one of eight 74HC4040 counters when a pulse is in-range. Because the energy width represented by the eight counters is selected to be just slightly larger than the natural width of the 185 keV U-235 line as generated by the NaI phototube, the 185 keV line shows up on the eight channel display as a rough outline of a peak. The peak is centered in the display with the two outer-channel l.e.d.'s back down at background level.

Display-of-the-contents of the eight 12-bit counters is achieved as illustrated in Figure 4 and described below. The 74HC404 binary counter type memory is incremented "serially" by toggling the appropriate counter clock line. The 74HC4040 counter chips also have pins giving the on/off status of each of the twelve binary bits so the contents are continually available in "parallel" format. An AD654 oscillator serves to generate a "horizontal sweep" for displaying the contents of the "memory". This oscillator drives a 74LS93 counter to generate a three-binary-bit horizontal address (ie, $2^3 = 8$ addresses). This three-line address is routed to all the 74LS251 1-of-8 line selector chips as well as to the detector/display electronics so that both portions of the system know which of the eight counter contents is being routed to the display. The appropriate on/off contents of the 2^{11} through the 2^4 binary bit weights of that counter are passed in parallel fashion through the eight 74LS251's. Five of these bit weights (as selected by the sensitivity selection push buttons on the hand-held portion of the system) pass through the 2 1/2 74LS253's (dual 4-line-to-1-line selectors) to the handheld detector/display, electronics. There, two 74LS154's convert the 5-line-binary bit weight to a 1-of-32-line vertical output. The one-of-thirty-two lines selected turns on a single l.e.d. at the appropriate vertical (and horizontal) location. All eight memory elements (counters) are scanned and displayed about

30 times per second to give the appearance of a constant display. The remote four button sensitivity selection made by the operator is sent from the display to the back pack electronics by the 2-binary line set called "A, B sensitivity control."

Figures 5 through 15 completely document the wiring of both the back-pack and the hand-held portions of the electronics. The functions covered by each of the Figures is listed in the index. Figures 5 through 12 deal with the back-pack unit and Figures 13 through 15 deal with the hand-held portion of the system. The following page lists vendors for some of the more specialized components used.

Speciality Components and Their Respective Sources

HAS 1212 12 bit analog to digital converter	Analog Devices Computer Labs Greensboro, N.C. 27409
AD 654 horizontal display oscillator	Analog Devices Norwood, Mass 02062
PWR 611B 12V to ± 15 volt converter	Burr Brown Tucson, Ariz 85734
PWR 606B 12V to +5 volt converter	Burr Brown Tuscon, Ariz 85734
PMT-10A-P, option #3 0 to 1000 volt (regulated)	Bertan Associates Hicksville, N.Y. 11801
2M2/2 #2" dia x 2" long, NaI, photomultiplier	Bicron Corp. Newbury, Ohio 44065
HA 2525 operational amplifier	Harris Corp. Palm Bay, Florida 32905
HA 2515 operational amplifier	Harris Corp Palm Bay, Florida 32905
IEE LR7057R3 5 x 7 dot display	Industrial Electr. Engineers Van Nuys, Calif 91409
GRC 12750N battery, 12 volt	Johnson Controls (Globe) Milwaukee Wisc. 53201
GRC 12750N external charger	Johnson Controls (Globe) Milwaukee, Wisc. 53201
1N5820 Schottky diode (low voltage drop)	Motorola Corp. Phoenix, Ariz. 85036
10823-001 5.8 x 10.1 x 10.3 carrying case	Schroff Instrument Cases Warwick, R.I. 02885
TC-145 photomultiplier preamplifier	Tennelec Oakridge, Tenn 37831

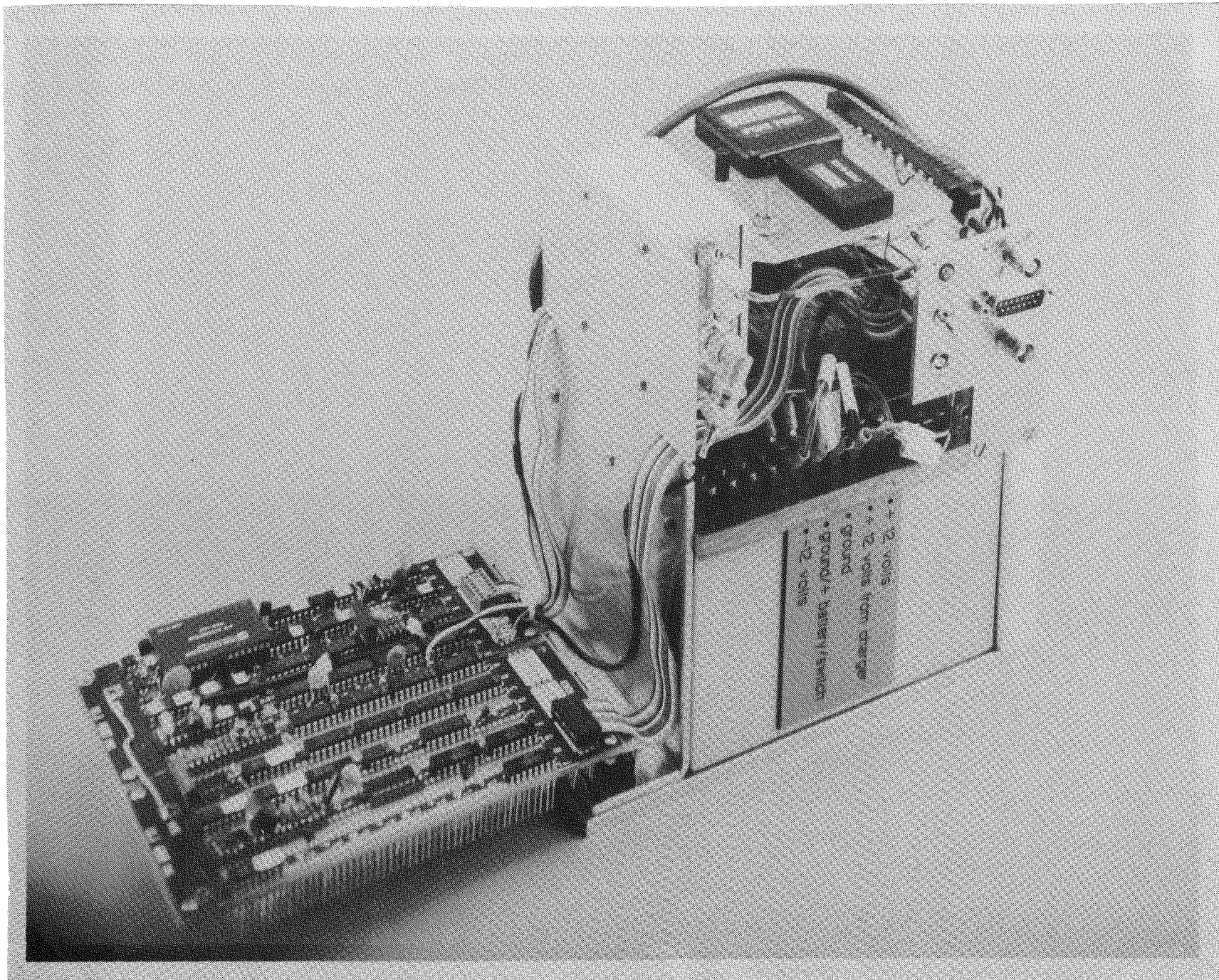


Figure 1. Back Pack Electronics with Main Board Folded Outward

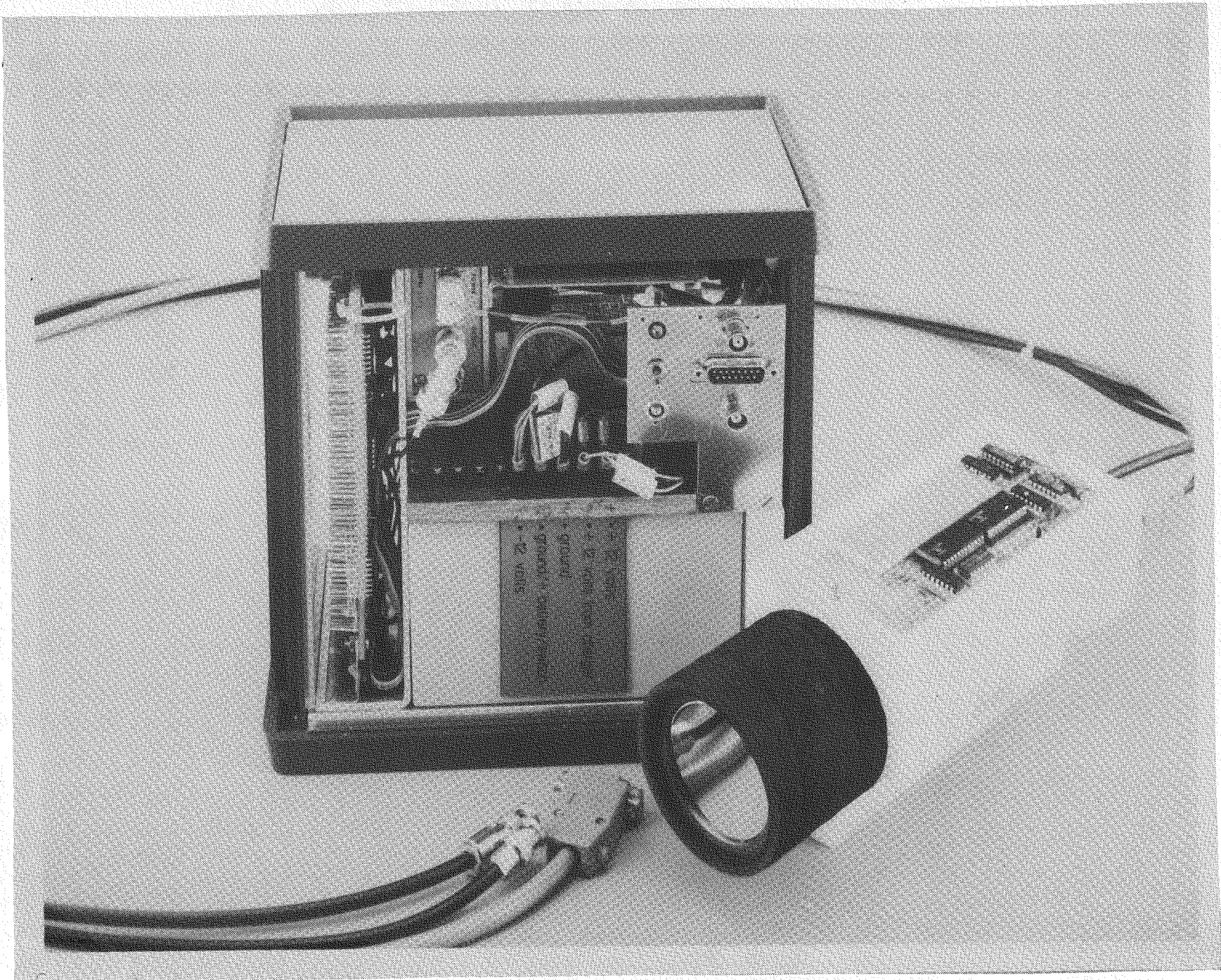


Figure 2. Total PHA System with Back-Pack Side and Covers Off

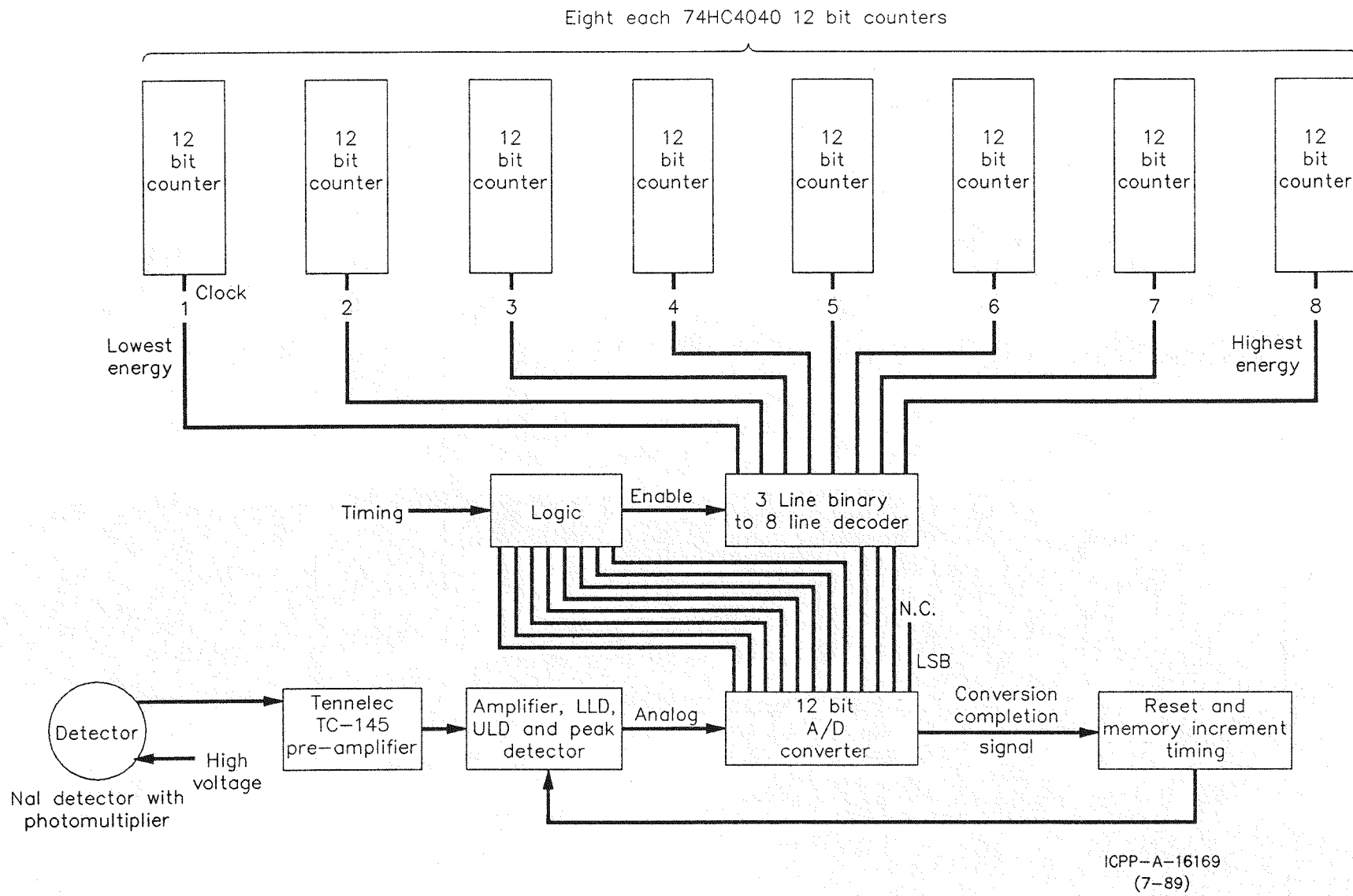
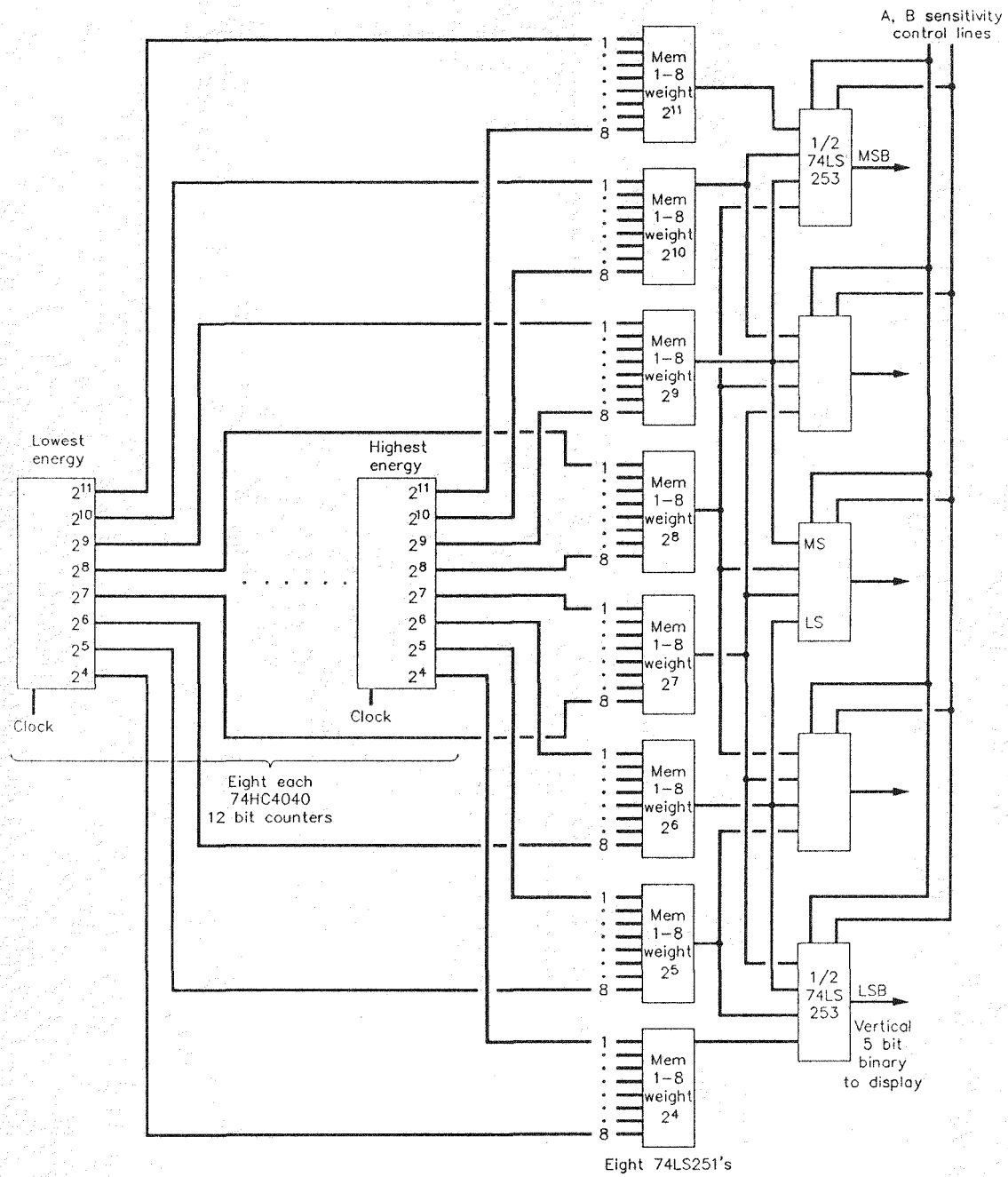


Figure 3. Pictorial of Pulse Routing, A-to-D Conversion and Memory Registration



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Figure 4. Pictorial of Memory Examination and Display with Selectable Sensitivity

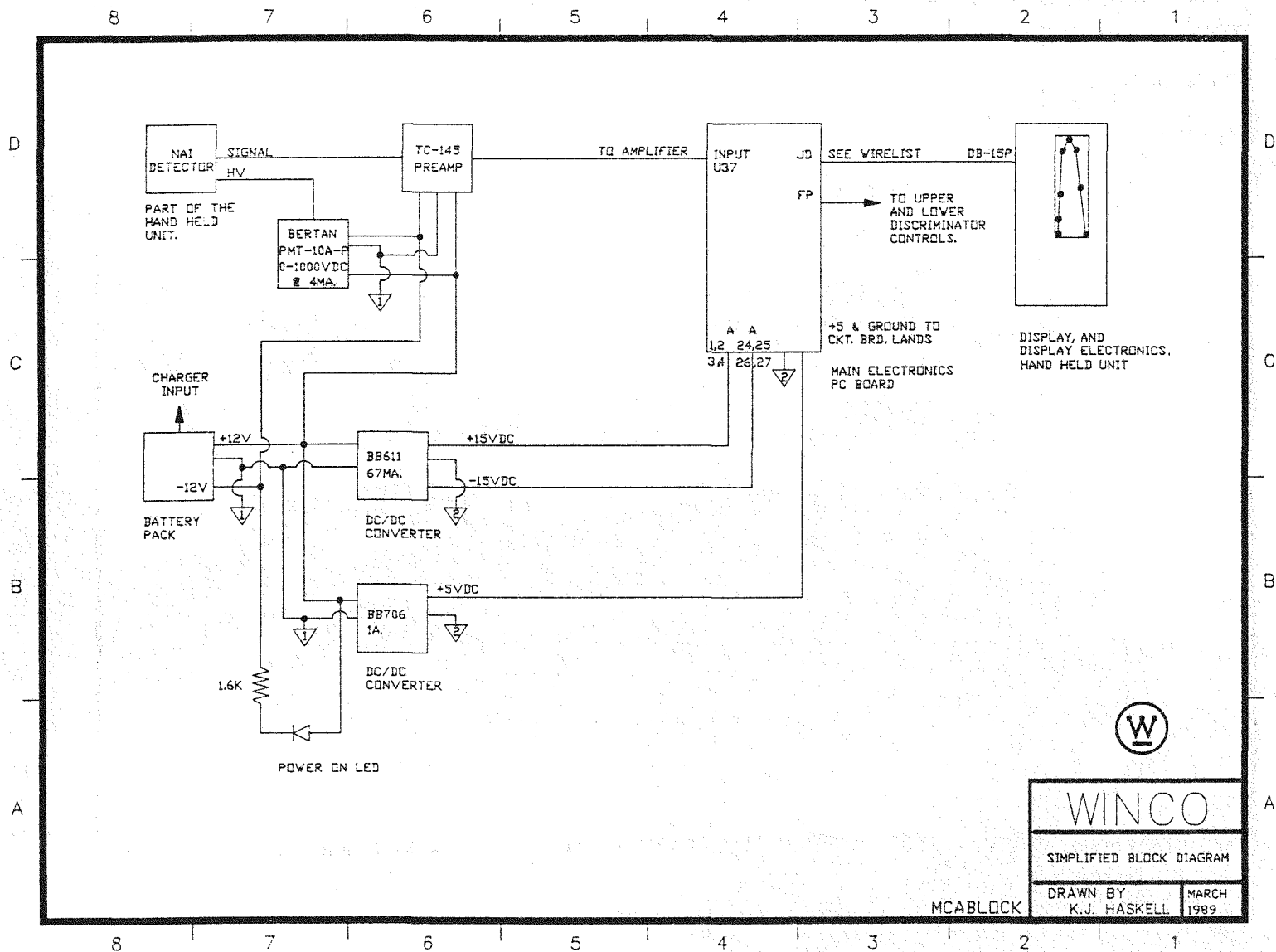
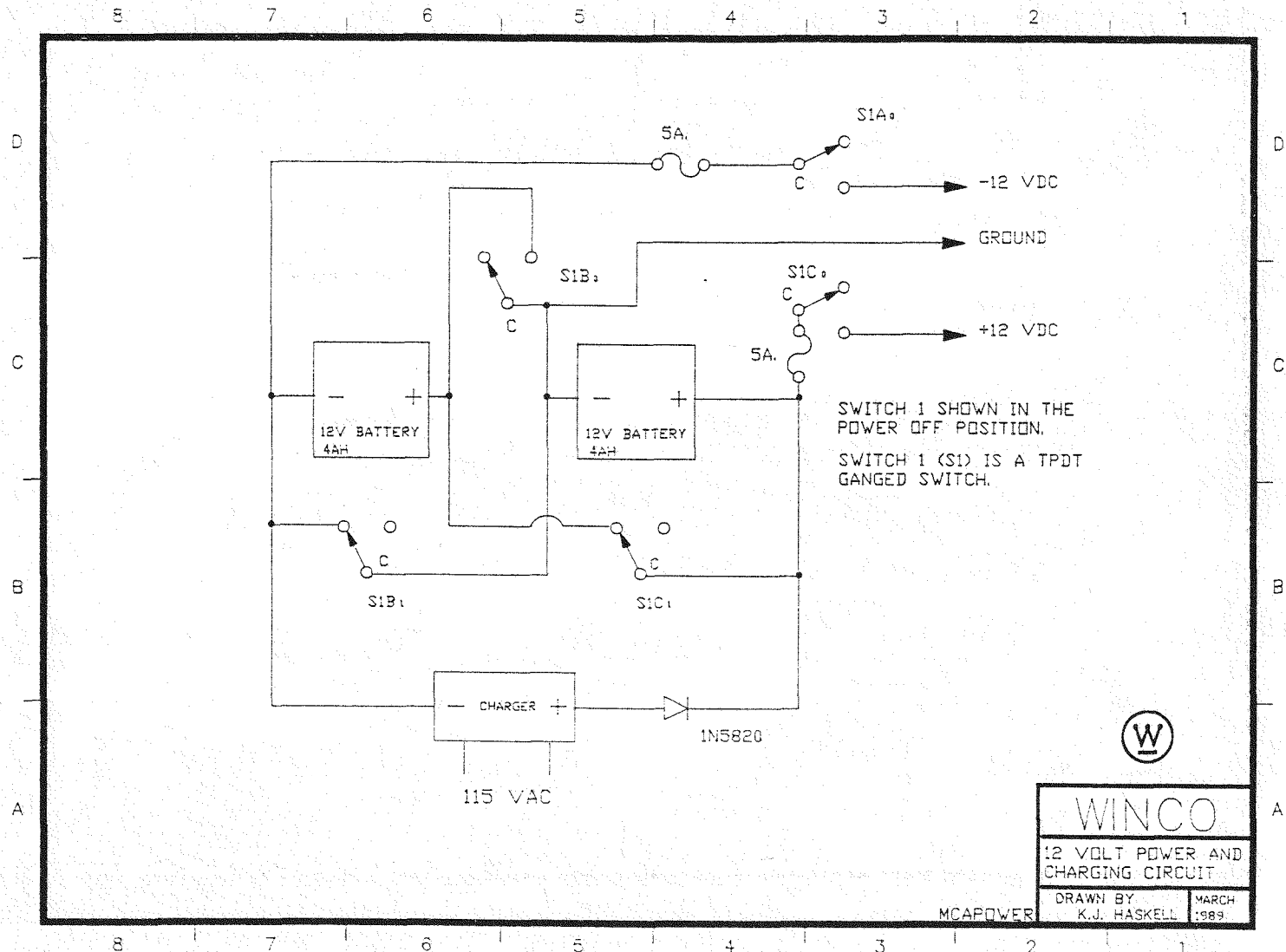


Figure 5. Basic Power and Signal Flow Pictorial

WINCO
SIMPLIFIED BLOCK DIAGRAM
DRAWN BY K.J. HASKELL MARCH 1989

MCABLOCK

10




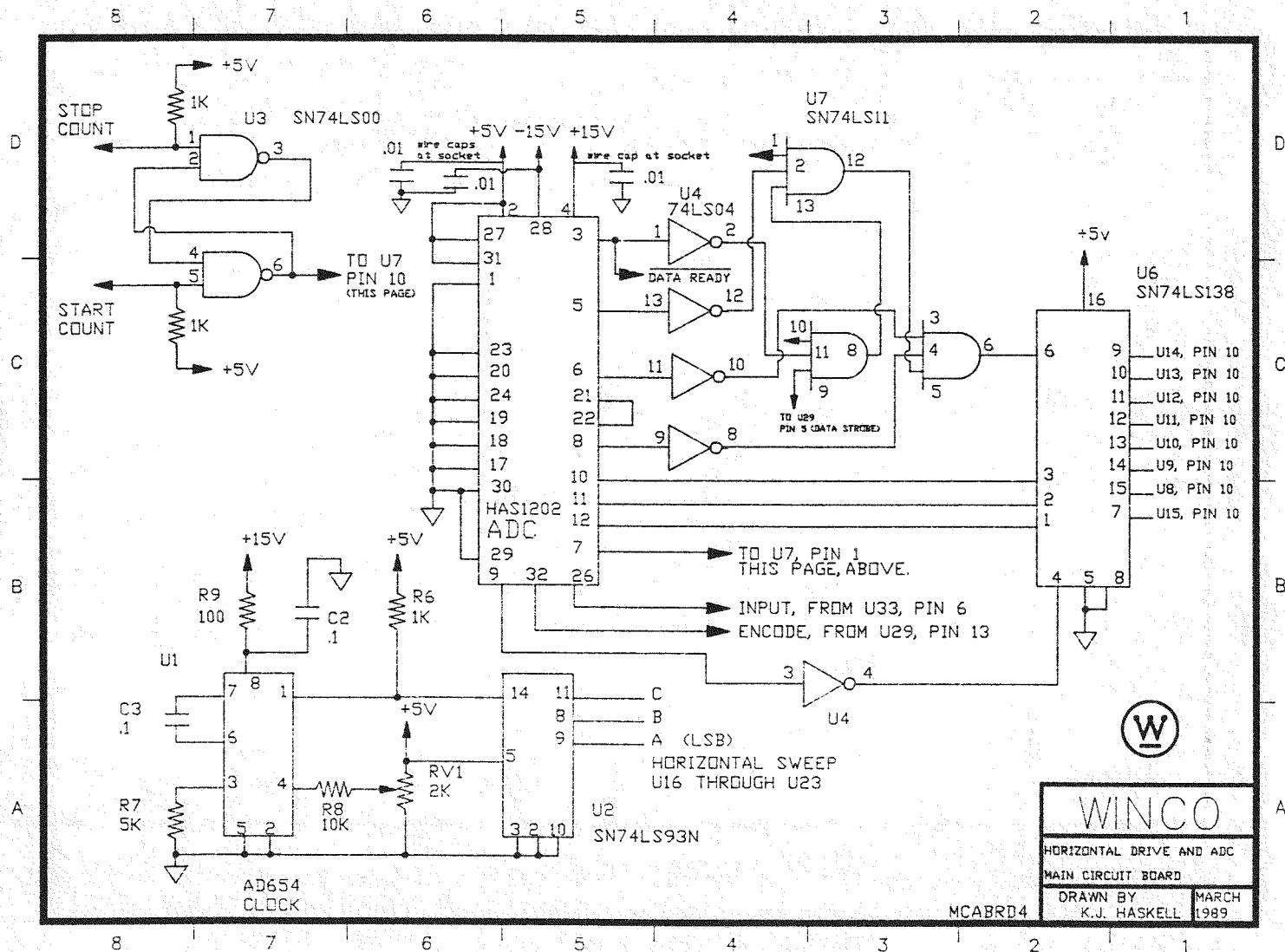

WINCO
 12 VOLT POWER AND
 CHARGING CIRCUIT
 DRAWN BY K.J. HASKELL MARCH :989

Figure 6. Battery Operate and Recharge Configurations



WINCO

HORIZONTAL DRIVE AND ADC
MAIN CIRCUIT BOARD

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Figure 8. ADC, Horizontal Display Oscillator

MCABRD4

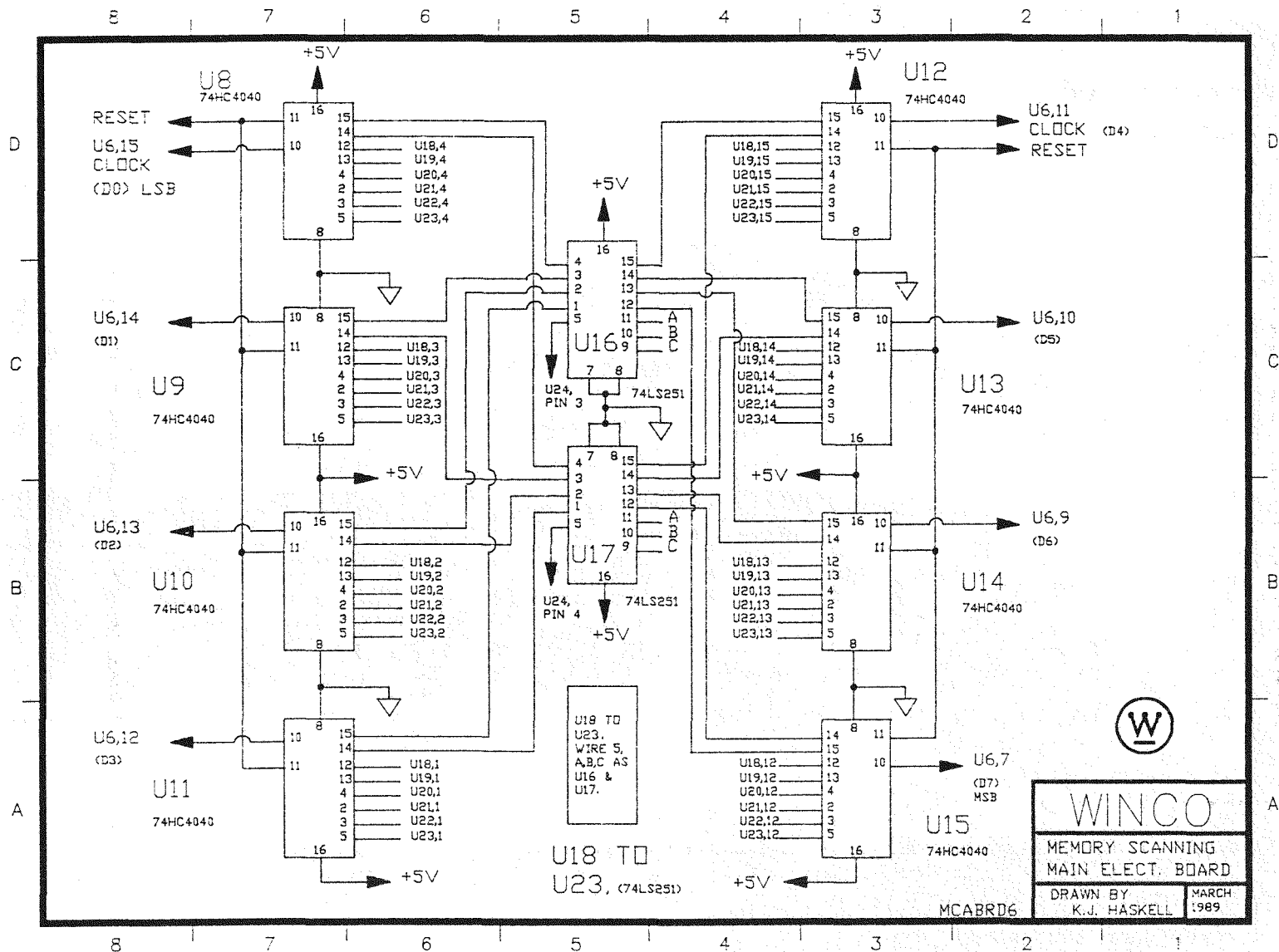



Figure 9. Memory Scanning by 74LS251's per 3 line Horizontal Address


WINCO
 MEMORY SCANNING
 MAIN ELECT. BOARD
 DRAWN BY K.J. HASKELL MARCH 1989

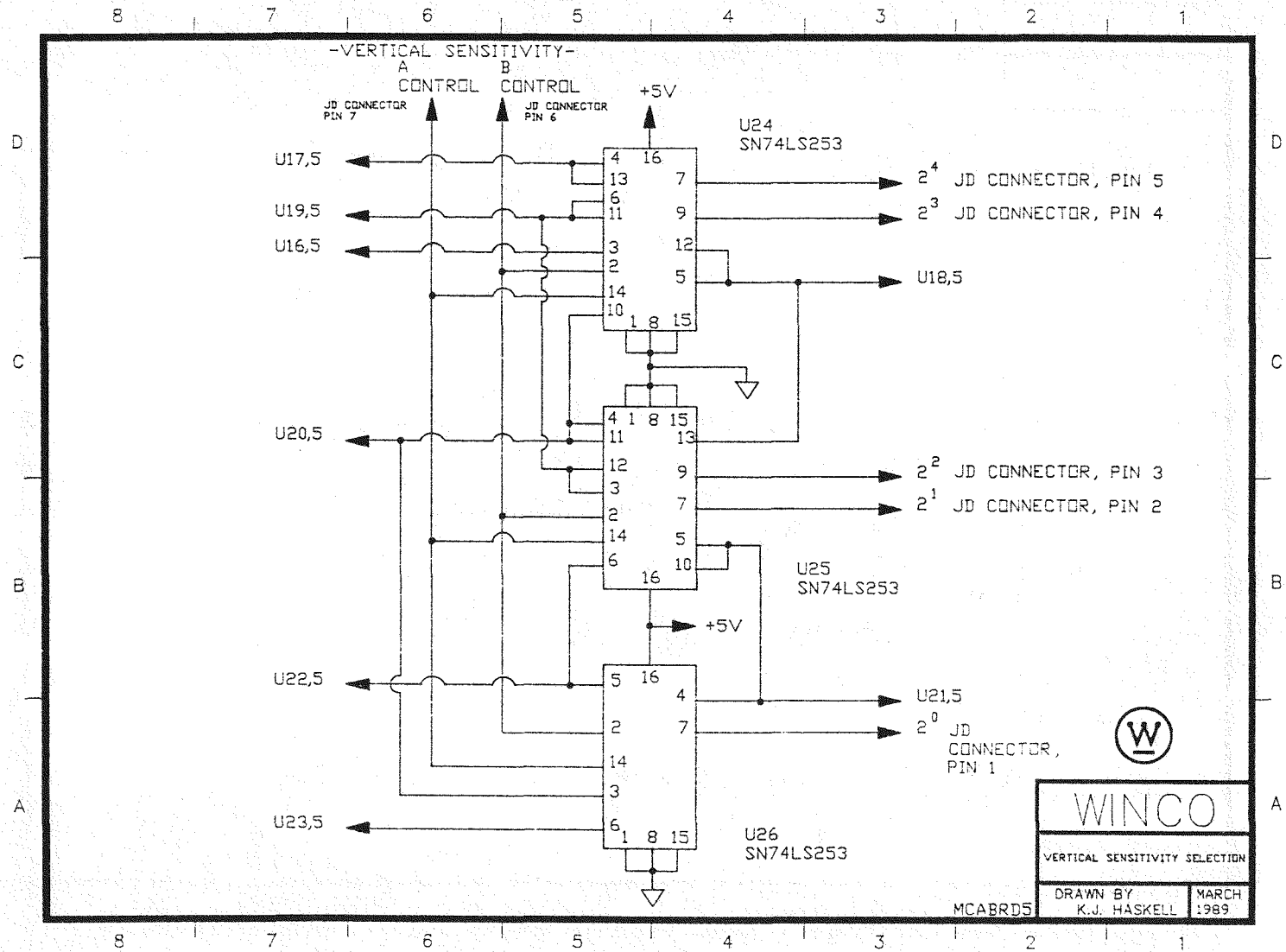


Figure 10. Vertical Sensitivity Selection per 2-line "A, B Control" Lines

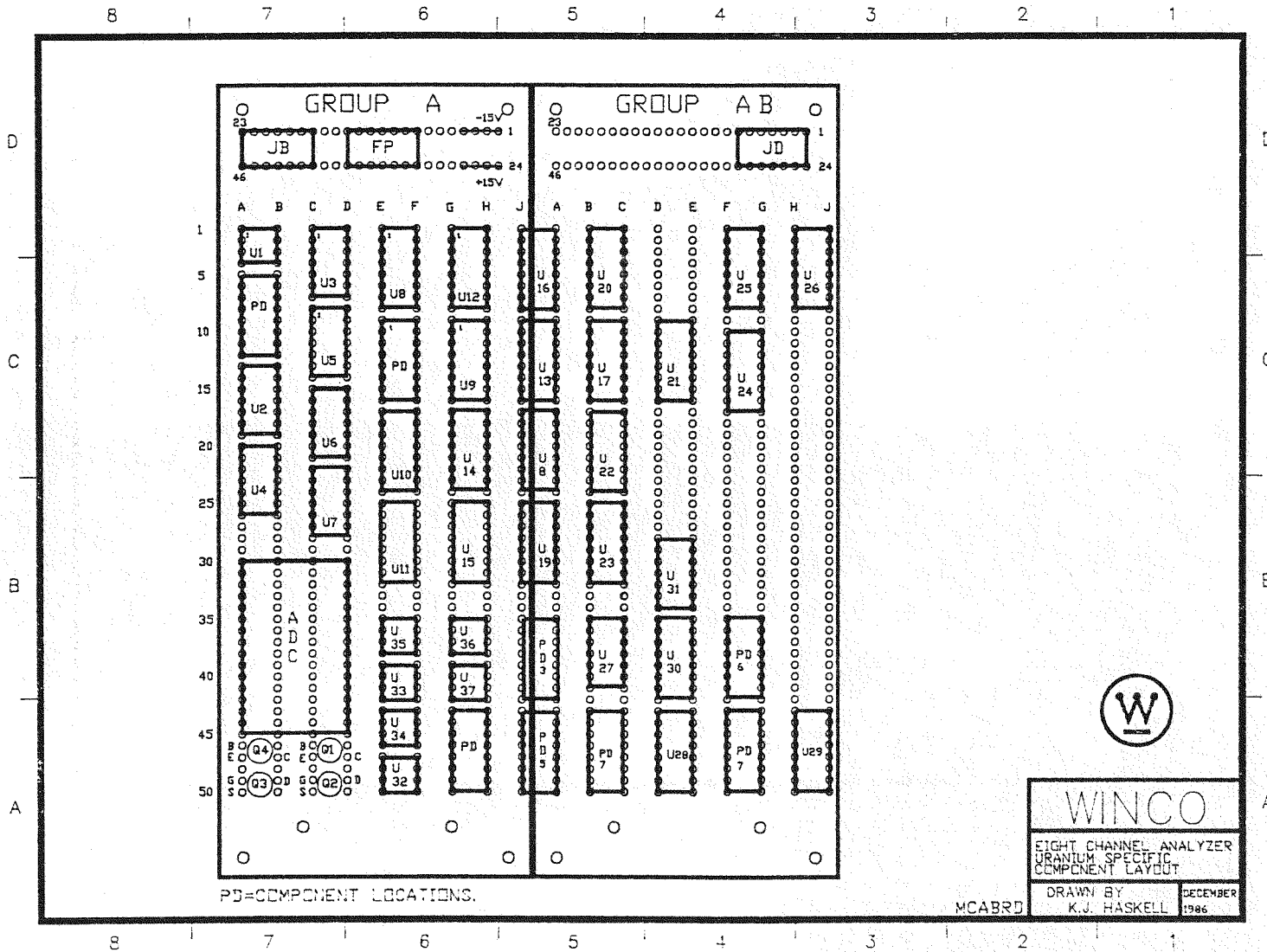


Figure 11. Component Locations on Main Circuit Board

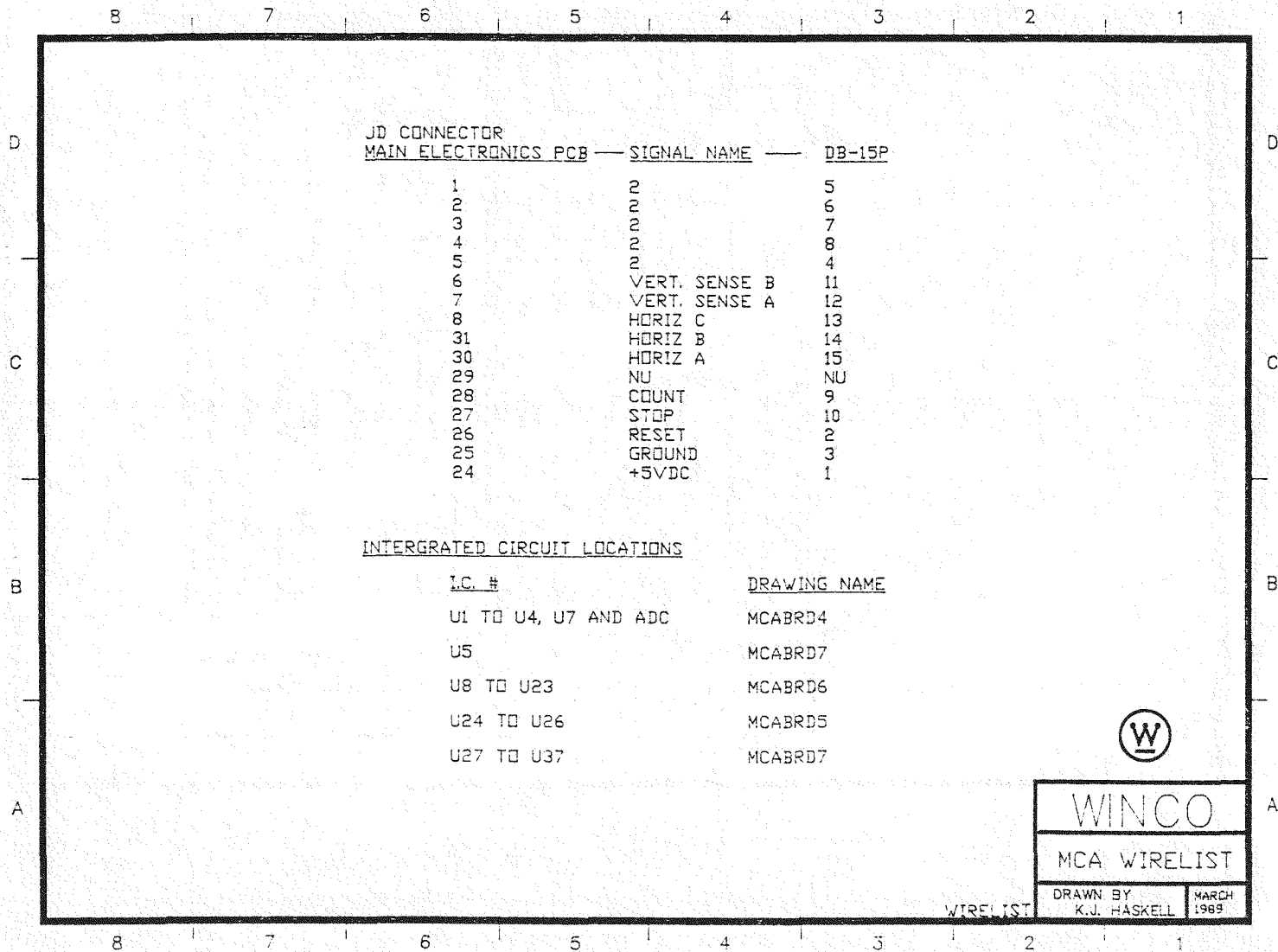


Figure 12. Back Pack Component Locations and Interconnect Wiring to Hand Held Unit

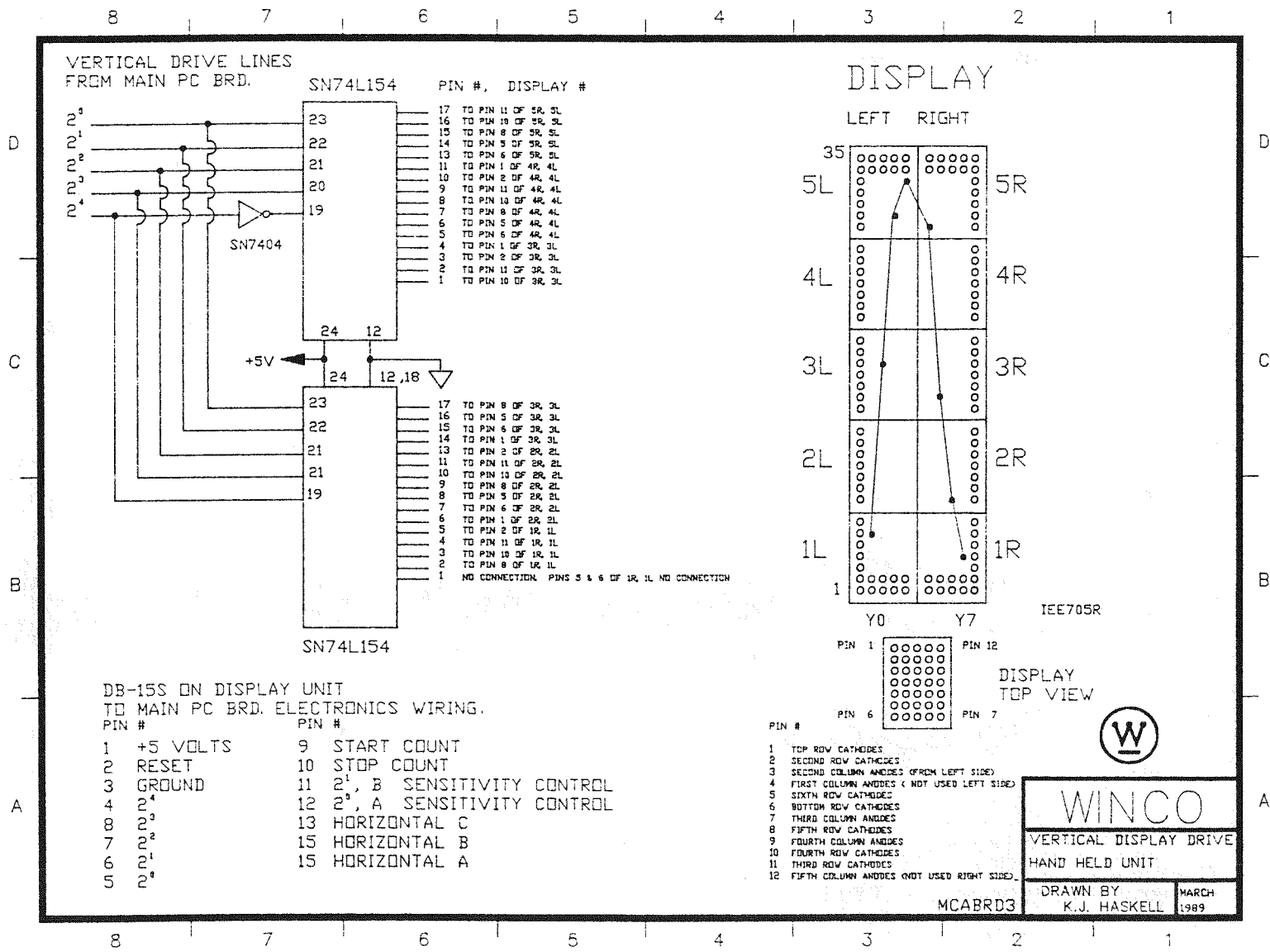
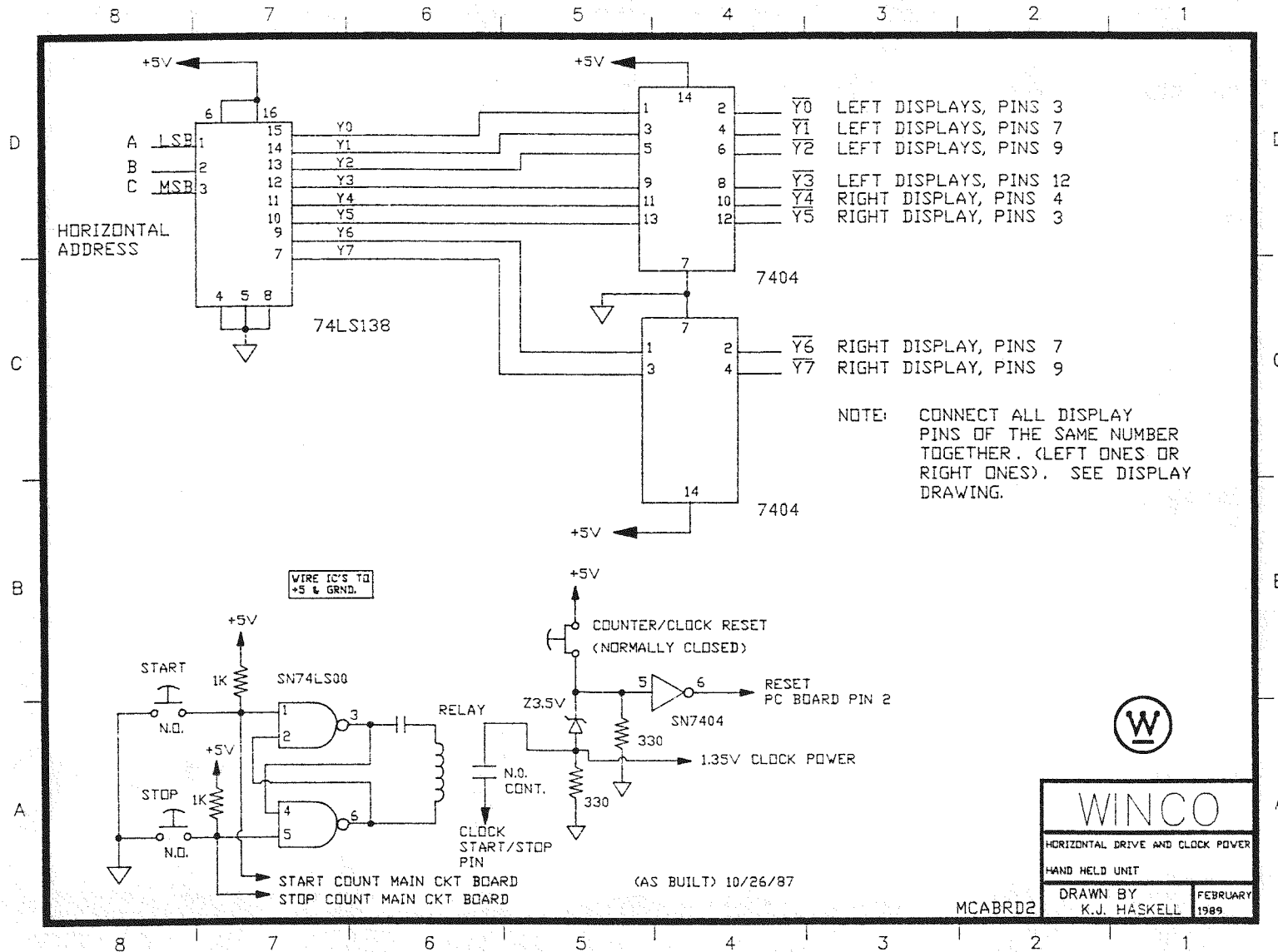


Figure 13. Pictorial of Display, 5-line to 1-of-32 line Vertical Decode



NOTE: CONNECT ALL DISPLAY PINS OF THE SAME NUMBER TOGETHER. (LEFT ONES OR RIGHT ONES). SEE DISPLAY DRAWING.

(W)

WINCO

HORIZONTAL DRIVE AND CLOCK POWER
HAND HELD UNIT

DRAWN BY K.J. HASKELL	FEBRUARY 1989
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MCABRD2

(AS BUILT) 10/26/87

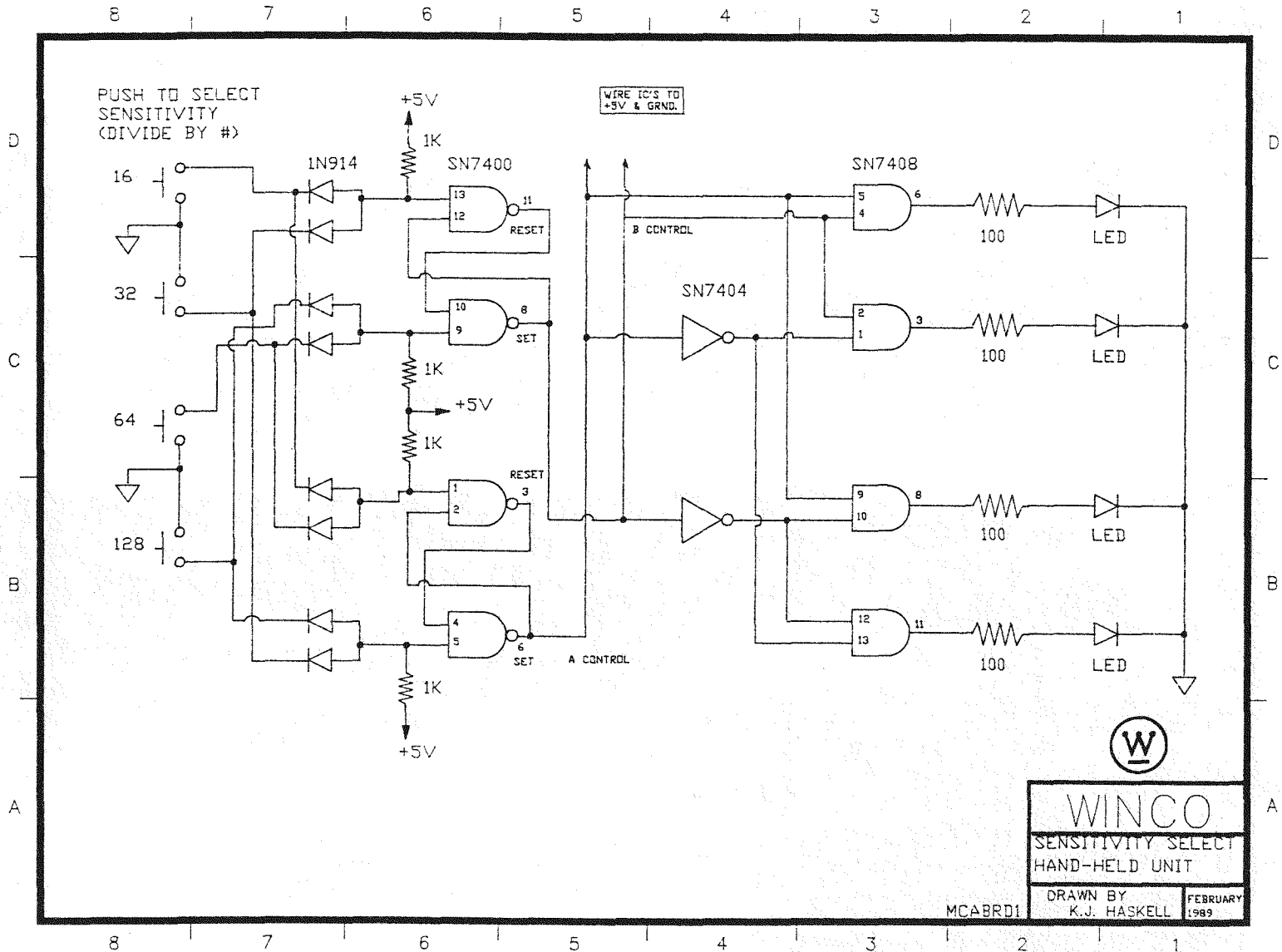


Figure 15. Generation of 2-line "A, B Sensitivity Control" for 4 Sensitivity Push Buttons