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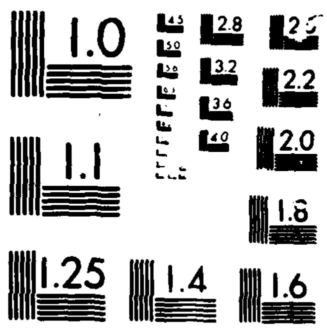

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TECHNICAL REPORT

EASY PROJECTION OF STEREO MOVIES

by

Noel Bartlett, G. Andrew Erickson, Donald H. J. Mackay, Kent R. Wilson

Prepared for Publication

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Department of Chemistry
University of California, San Diego
La Jolla, CA 92093

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ABSTRACT

A new method is described for showing colour stereo movies with arbitrary movie projectors by the means of a small portable adapter. The beam from an ordinary movie projector is passed through a linear polarizer followed by a crystal which rotates the angle of polarization under voltage control, so that alternating left and right images are polarized 90 degrees apart. A photodiode and a sensing circuit synchronize the polarization shift to the flicker of the projector shutter. The adapter is small, self contained, and needs only be placed in the path of the projected beam.

Keywords: stereo, movie, molecular graphics

* Author to whom correspondence should be addressed.

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April 15, 1986

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I. INTRODUCTION

The perception of depth is basic to our assimilation of information in a three dimensional (3-D) world. In the field of chemistry, the three dimensional structure of molecules is essential to understanding the function, interaction and dynamics of chemical systems. However, with the exception of physical models, three dimensionality is largely limited to two dimensional projections. Several visual effects can be used to convey the impression of depth. Shading, intensity attenuation with depth, hidden surface removal, and motion (particularly rotation) provide useful depth cues which are usually sufficient for objects with which the mind has had previous 3-D experience, such as models of automobiles or buildings. Molecular models, however, are abstract. Stereoscopic perception (each eye seeing a different perspective of the image allowing the brain to perceive the image in three dimensions) has therefore become very useful for visualizing complex molecular models, especially those composed of many atoms such as large biological molecules.

Stereo imaging has been accomplished in various ways, the simplest and oldest being the stereoscope which places left and right images of a scene in front of the respective eyes and prevents each eye from seeing the other image. Several variations on this theme have been devised using more elaborate eye - image selection schemes and have been implemented on various media including television, printed material, and computer graphics.[1] These include colour filtering (red and green images filtered through coloured glasses),[2] polarized filtering (images composed of polarized light rotated 90 degrees from each other and viewed through polarizing filters), mechanical shutters (rotating shutters which allow only one eye to see at a time, coupled with a synchronous display which shows the appropriate image for each eye), and electronic shutters (similar in concept to mechanical shutters but replacing the rotating disk or cylinder with an electronically switched device, for example, a sandwich of polarization rotating crystal between polarizing filters).[3,4]

Each of these techniques relies upon tricking the mind into perceiving a 3-D image, using a pair of 2-D images. In addition, "true" 3-D images can be reconstructed, for example holograms.[1] A novel approach uses a vibrating mirror to reflect a computer generated image which is synchronized to the current position of the vibrating mirror.[5] True 3-D representations have the advantage that one can perceive the same model from different viewpoints.

While each of these methods is useful in its own context, most are limited by the need for specialized, often expensive, equipment which can conveniently be used by at most a few people at a time. One would like a simple and inexpensive means of conveying to larger audiences, 3-D information about systems which change with time, for example, the molecular dynamics by which chemical processes take place. Stereo movies have been made for many years, but require specially modified (and usually expensive) projectors which are often bulky (some schemes actually require two synchronized projectors) and non-universal. We describe here a simple apparatus costing less than $1000 which enables any style or make of movie projector to display stereo films. This apparatus is easily portable and has been tested over the past few years with a large variety of commercial movie projectors. It could equally well be adapted to live action film or projection TV.

CONSTRUCTION

The technique requires that the film be prepared so that left and right images occur on alternate frames. In computer animated films, this is accomplished by shooting each image twice, alternating the perspective of the image by a small angle between exposures. To increase the stereo effect, the image to be viewed in 3-D is rotated around a point which would be the back of the model if the image was actually physically present. The amount the image is rotated was experimentally derived to give an image which was as flickerless as possible, but also has a sufficient stereo "depth". A rotation of 1.75 percent of the picture width was found to produce the best quality 3-D image. In addition, the use of perspective by shrinking the size of objects which are farther away helps the mind perceive the images in 3-D. For non-computer animated films, specialized camera equipment is necessary. Standard techniques include mounting two cameras side by side to synchronously expose left and right images. The two films could then be interlaced using an optical printer. Alternatively, a single camera with a double lens and a left/right shutter to select alternating lenses can expose the left and right images directly.

The apparatus described here consists of four basic components: *i)* a polarization control assembly with an initial polarizing filter and a polished and electroded lead lanthanum zirconate titanate (PLZT) transparent ceramic wafer which can be voltage controlled to rotate polarized light (see figure 1), *ii)* a synchronizing circuit to monitor the flicker rate of the projector using a light sensitive diode placed in the light path, *iii)* a voltage switching circuit to switch the voltage to the PLZT wafer between stereo pair frames, and *iv)* a power supply for the PLZT wafer.

The apparatus functions by a three stage filtering process. First, the assembly polarizes the light to one particular orientation (for example, suitable for left eye viewing). Then, under voltage control, the PLZT wafer can rotate this light 90 degrees, thereby creating a right eye image. When to rotate the image is determined by a sensing circuit which samples the flicker rate of the projector and switches the crystal voltage on and off on alternate frames. The final outcome is a stream of images composed of pairs of polarized frames rotated by 90 degrees with respect to each other.

The image stream must then be reflected from a non-depolarizing screen. The final filtering occurs through polarizing spectacles worn by the viewer with the right eye filter oriented to exclude left images (e.i., oriented 90 degrees relative to the incoming left image light), and vice versa, producing the stereo effect by allowing left and right images to be seen only by their respective eyes.

The PLZT wafer is commercially available from Motorola's Ceramic Products Division* and is produced in two thicknesses (0.020 and 0.040 inch) requiring different voltages (280 and 520 volts, respectively) and in various packages. We have found the lower voltage (thinner) wafer to be preferable, in spite of a 25% higher price, since the required voltage is more manageable. We have found the bare ceramic wafer to be very fragile and prefer a glass sandwich package which protects it from breakage and humidity. The sandwiched version usually contains two polarizing filters oriented 90 degrees relative to each other on either side of the filter to act as a voltage dependent light shutter. Our application uses it as a voltage dependent light rotator and so needs only the leading filter. Motorola kindly provided us with a sandwich version without polarized filters. The price of the 0.020 inch wafer (part number A20CE20BA) is approximately $395.

The most general way to synchronize the polarization rotation is to sense frame advances by monitoring the light coming from the projector. This scheme is complicated by the fact that movie projectors chop each frame into several (almost always 2 or 3) flashes to increase the apparent refresh rate and thereby reduce perceived flicker.

The circuit which monitors the flicker of the projector consists of a photodiode which is placed directly in the path of the projected light. The projected image is not impaired because of the location away from the focal plane. As a pulse of light is received, the photodiode sends a pulse to the counter section of the circuitry composed of two, 4-bit bi-directional serial-in, parallel-out shift registers and associated driver circuitry (figure 2, U14 and U15). The synchronization circuitry uses a comparator (U2) and locking circuitry (U4) so that when synchronization occurs, the apparatus stays locked. The manual sync circuitry consists of a LED display which indicates how many fractions of a frame the operator has changed from the original synchronization, and two buttons to allow shifting the

*Motorola Corporation 5005 E. McDowell Road Phoenix, Arizona 85008 U.S.A.

synchronization either forward of backward. The output of the synchronization circuitry used to control the voltage to the PLZT is taken from the second or third bit of the shift register depending on whether the particular projector chops each frame into two or three flashes. To simplify the procedure of synchronization, an auto-synchronization feature is provided which uses a test leader of alternating black and white frames inserted at the beginning of each movie. The photodiode is able to distinguish between black and white frames and therefore the unit can synchronize itself to these frames (when in auto-synchronization mode) on the leader and relieve the operator of any manual intervention. Due to the sensitivity of the photodiode in the infrared, and the transparency of even black frames of film in the infrared, the unit remains synchronized throughout the movie .

The voltage required for the PLZT wafer is controlled by a high voltage switching transistor which alternately turns a 325 volt power supply on or off with every frame pulse. The power supply can be varied from 250 to 400 volts, to correct for any differences in PLZT crystals and to balance the colour and intensity of the left and right images. With the proper voltage setting the colours of the projected images are virtually undistorted.

DISCUSSION

The overall stereo effect is very impressive. The main disadvantage of this method is that the effective refresh rate of standard movies is reduced from 24 frames per second to 12. Thus a noticeable, but not objectionable, flicker is present. This could be cured by increasing the speed of the projector but this would again lead to a non-portable system. The entire apparatus described above fits conveniently into a small box, 30 cm by 13 cm by 8 cm and is ideal for traveling (see figure 3). We feel this portability and usability with any projector far out weighs the small degradation in flicker perception.

ACKNOWLEDGEMENT

We thank the Office of Naval Research, Chemistry, and the National Science Foundation, Chemistry, for the support which made this research possible.

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PARTS LIST

Integrated Circuits

7404: U8, U19, U24
7408: U3, U17
7410: U5
7427: U10
7432: U7, U23
7447: U18
7474: U13
7495: U4
74121: U1, U6, U9, U11, U12, U22, U25
74190: U16
74194: U14, U15
74367: U20, U21
LM339: U2
7805: U26

Transistors, Diodes

ECG238: Q2
FPT16: Q1
600 V Bridge Rectifier: D1, D2
Red LED: L1, L2

Capacitors

20mf 600V: C6
1000mf 50V: C4
6mf 10V: C1
10mf 10V: C3, noise suppression
20mf 10V: C7, C8
1mf 10V: C9, C10, noise suppression
4mf 10V: C2

Resistors

430 ohm 1/8 W: R1
4.7K ohm 1/8 W: R3, R4, R17, R20, R21
22K ohm 1/8 W: R14, R16
1K ohm 1/8 W: R13, R15
100 ohm 1/8 W: R5, R12
100 ohm 1/2 W: R18, R19
18K ohm 1 W: R6
100K ohm 2 W: R8
22K ohm 1/4 W: R9
270 ohm 1/2 W: R10
10K ohm 1/4 W: R11
100K ohm 10 turn Heli-pot: R7
10K ohm 10 turn trim pot: R2

Switches

SPST Bat handle: SW1, SW2, SW3, SW7
DPST Bat handle: SW8
SPST Momentary: SW4, SW5, SW6

Miscellaneous

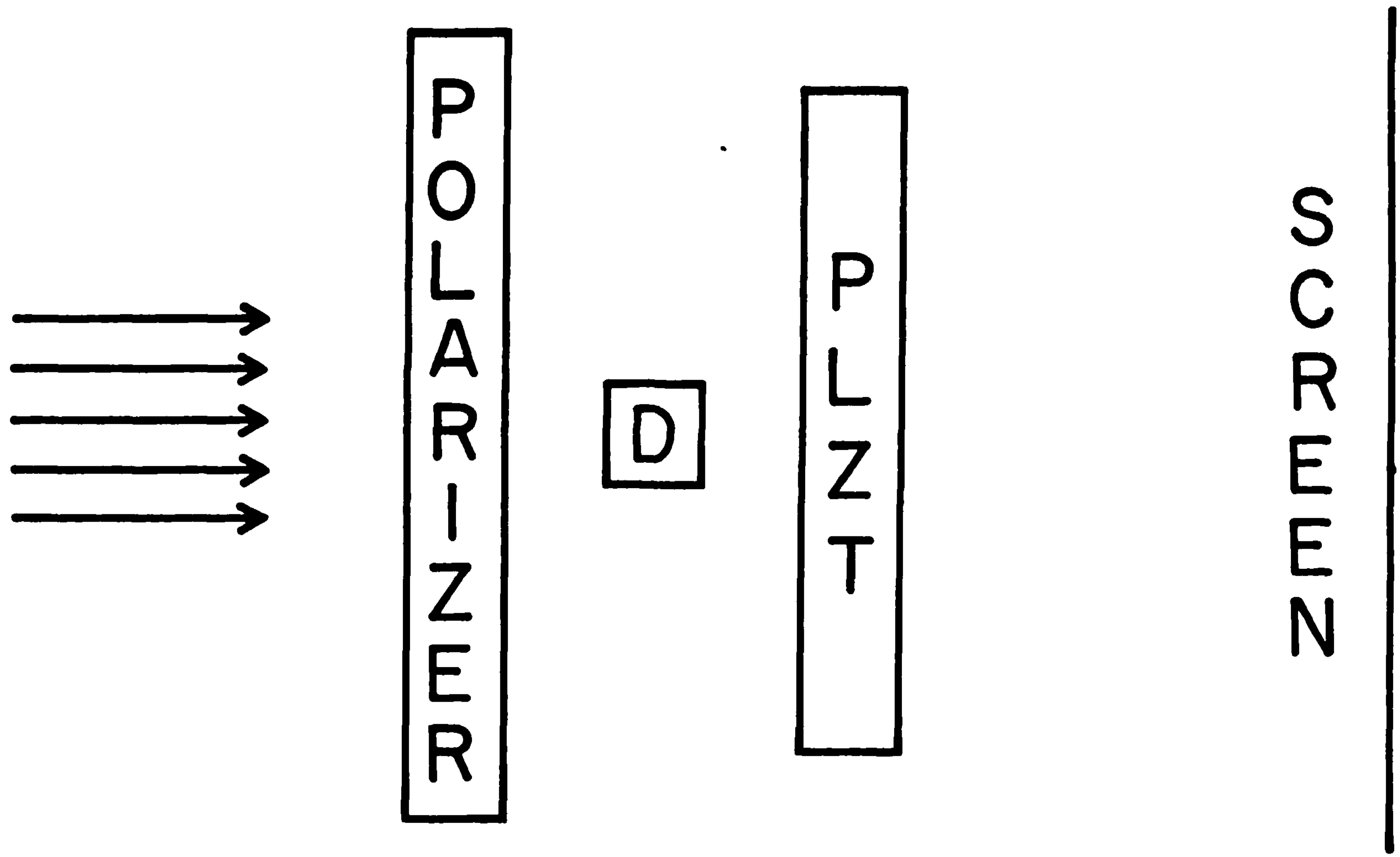
110/220 VAC Isolation transformer
6.3 VAC, 500 VAC secondary transformer
1 1/2"   280 Volt PLZT Crystal
2 Amp Fast blow fuse: fuse 1

FIGURE CAPTIONS

Figure 1. Stereo projection unit head containing a polarizing filter, a PLZT crystal for rotating polarization and photodiode (D) for shutter light pulse detection.

Figure 2. Schematic of stereo projection unit and associated power supply.

Figure 3. Physical representation of stereo projection unit and controls.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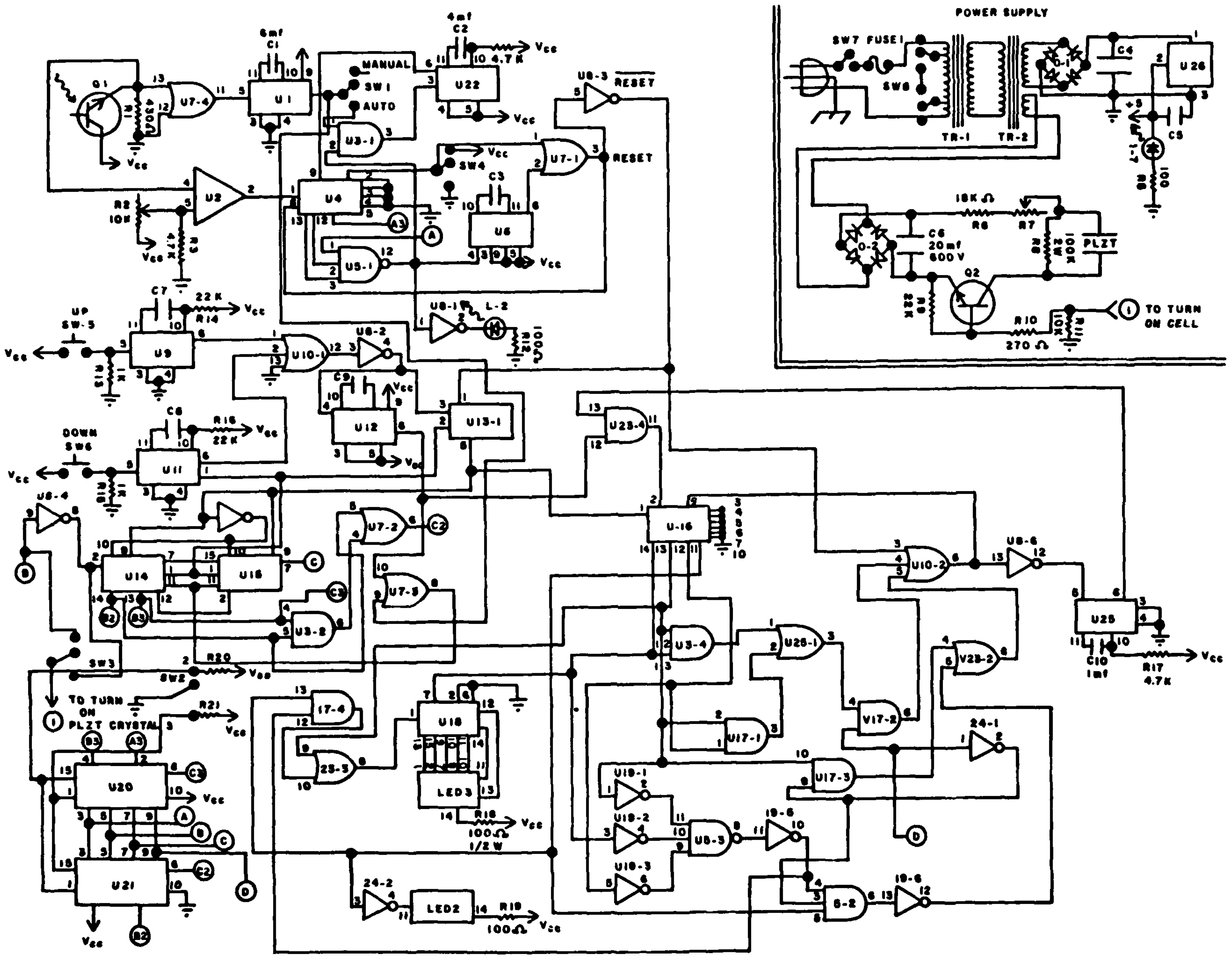
D
PLZT
SCREEN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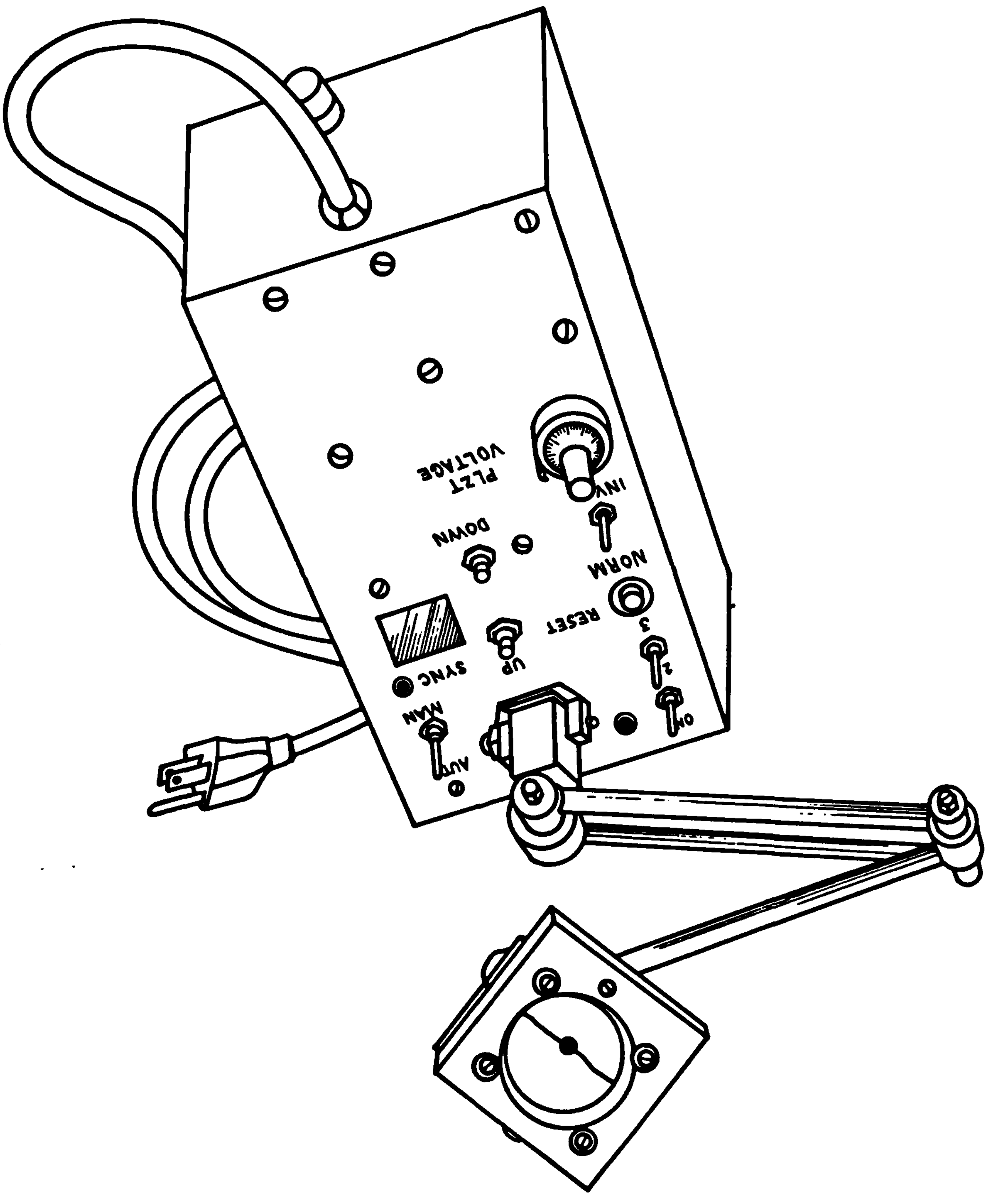
SW7 FUSE1
SW8
TR-1
TR-2
TO TURN ON CELL
TO TURN ON PLZT CRYSTAL
MANUAL
SW1
AUTO
RESET
UP SW-5
DOWN SW6
SW2
SW3
SW4
PLZT
LED2
LED3


PLZT
VOLTAGE
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