AUTOMATIC GENERATION OF ANTERIOR HORN CELL REFRACTORY CURVE

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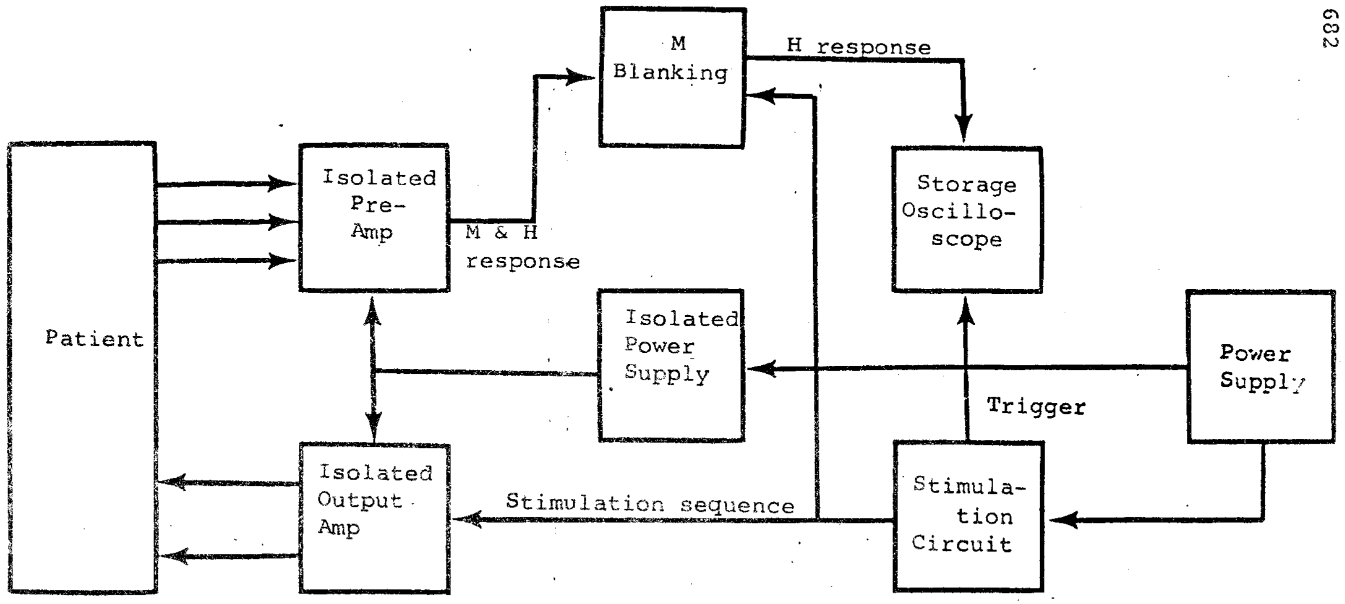


FIGURE 1

SYSTEM BLOCK DIAGRAM

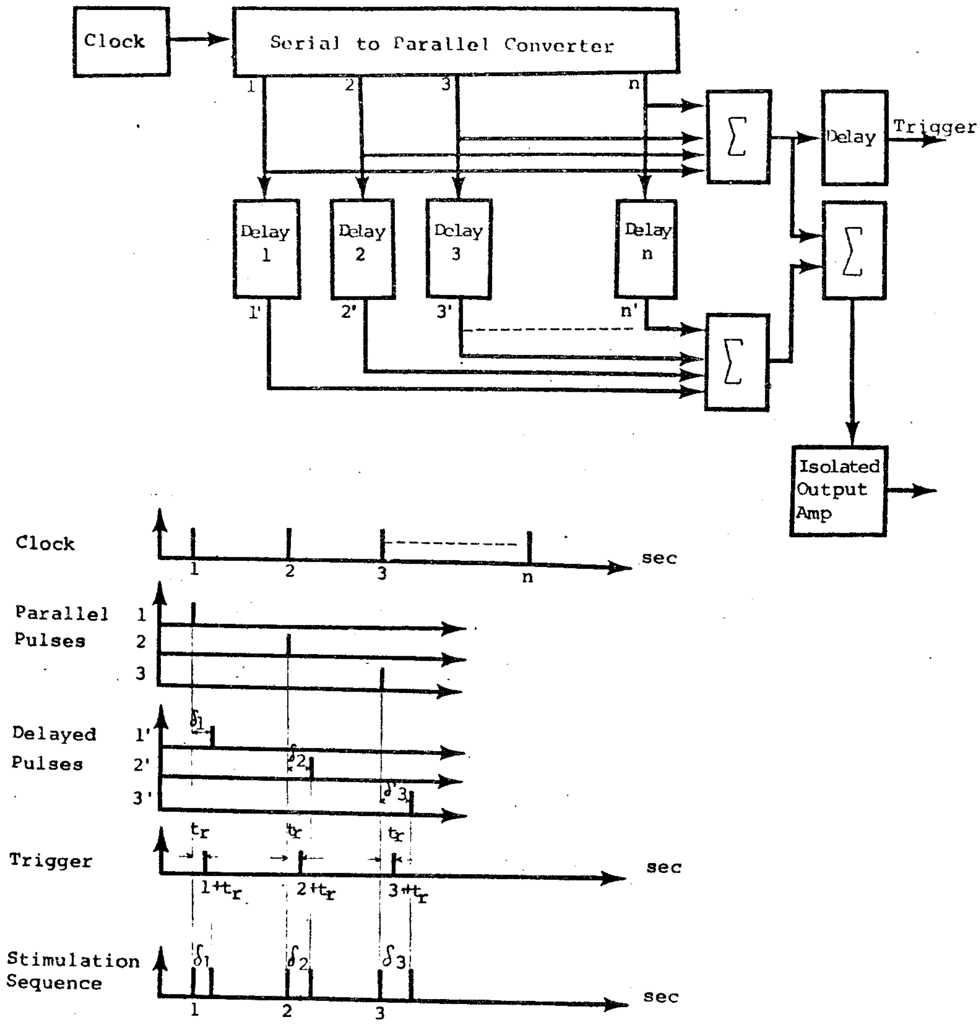


FIGURE 2

STIMULATION PULSE GENERATOR BLOCK DIAGRAM

Illis et al (1) have published data to the effect that refractory curves are subject to reversion towards a more normal configuration with stimulation of the dorsal column, i.e., this represents physiologic data obtainable on the ward, applicable to dorsal column stimulation. The electronic method whereby the above may be achieved more efficiently is the subject of this paper. As described in the above reference, the curves were obtained with a twin pulse generator. The second pulse following the first at a prefixed time interval and the sequence of stimulation consisting of a series of manually staged events. We have undertaken to develop a method whereby a refractory curve might be secured by a continuous automatic stimulation sequence. The overall block diagram of the system is shown in Figure 1. Figure 2 illustrates the stimulation pulse generator block diagram. It consists of a one Hertz clock which determines the basic repetition rate for the twin pulse sets. This clock signal is fed to a serial to parallel converter which separates a serial pulse train into a group of n parallel lines. Thus providing n lines which are independently programmed for n delays. The delayed pulses are then summed with the original pulses providing a combined signal which represents the desired stimulation sequence for the attainment of a recovery curve. The signal is then passed through an amplitude control which provides both for gross and microvolt amplitude variation, as well as patient isolation. The frequency of the clock is variable as well as the interval duration between successive twin pulses. The number of pulse pairs can be easily increased with the result that the limitation of the number of curve points to be plotted is restricted only by the ratio of duration time between pulses and the repetition rate of the clock frequency. This pulse chain can then be applied to the appropriate nerve site and the respective M and H reflexes are obtained for each stimulating pulse. The first three muscle responses are discardable in that it is only the second H which is of value for our purpose. The latter is more conveniently referred to as H. The remaining responses contribute nothing to the construction of the refractory curve. As seen in Figure 3C, all the responses bear a fixed time relationship to each other and given a set clock rate and pulse pair separation, the M and H reflexes must always follow at a fixed time interval. The only variable being the prefixed duration between the first and second pulses of the pulse pairs. In order to selectively display only the second H component, the M response which occurs after each stimulation pulse is blanked out for an appropriate period. See Figures 3C to 3E. In addition, the vertical axis of an oscilloscope is arranged to trigger at a constant time after the first pulse but before the second pulse of the pulse pairs, thereby inhibiting the first H response and displaying only the second H component. Figure 3B is an example of a twin pulse pair stimulating impulses with their respective M and H reflexes shown in 3C. The tabulation below Figure 4 is a detail of time intervals involved for the display of the respective H reflexes. The increment, as seen, has been chosen at fifty milliseconds, and in our case, the second H display times run from sixty milliseconds to 9,560 milliseconds. This tabulation is merely given as an example; any appropriate time sequence can be chosen following the choice of the initial interval duration between the pulses being used. Once again, the limitation in the system is the frequency of the clock rate with the result that in this case, the time interval required for the elicitation of the tenth H reflex is 9,560 milliseconds. This allows more than adequate time for the commencement of the next twin pulse stimulation. The smaller the delay increments, that is to say for 10, 20, 30, and 40 msec. respectively, the greater will be the number of points attainable for plotting the refractory curve. At this point, we have covered the sequence of H reflexes elicitable at 50, 100, 150,.. to 500 milliseconds, respectively. Although these values do not represent absolute values, they can be looked upon as valuable in a referential sense; the 400 msec. H amplitudes being taken as the standard. All of which assumes that the electronic amplification and nerve muscle attenuation characteristics remain constant throughout the duration of the stimulation run. A storage oscilloscope must be used to display the respective H amplitudes. The refractory curve is then the peaks of these individual pulses and may be plotted as a curve rather than a series of vertical deflections by various electronic means. Up to this point, the cost entailed has been quite limited but increases beyond this stage in proportion to the computational operations to be carried out. In Figure 5, we have defined several characteristics of the refractory curve: 1. Recovery index which is an indication of the rise time or recoverability rate of the anterior horn cells; 2. Steady State Index which is an index of the resting potential of the cell; 3. Overshoot Index which is a measure of deviation from normal or steady state. The clinical significance of each of these characteristics will be elaborated in four examples.

In conclusion, it is possible that data obtained in this fashion may permit better understanding of the manner in which spinal cord stimulation may be more appropriately applied in various neurological states.

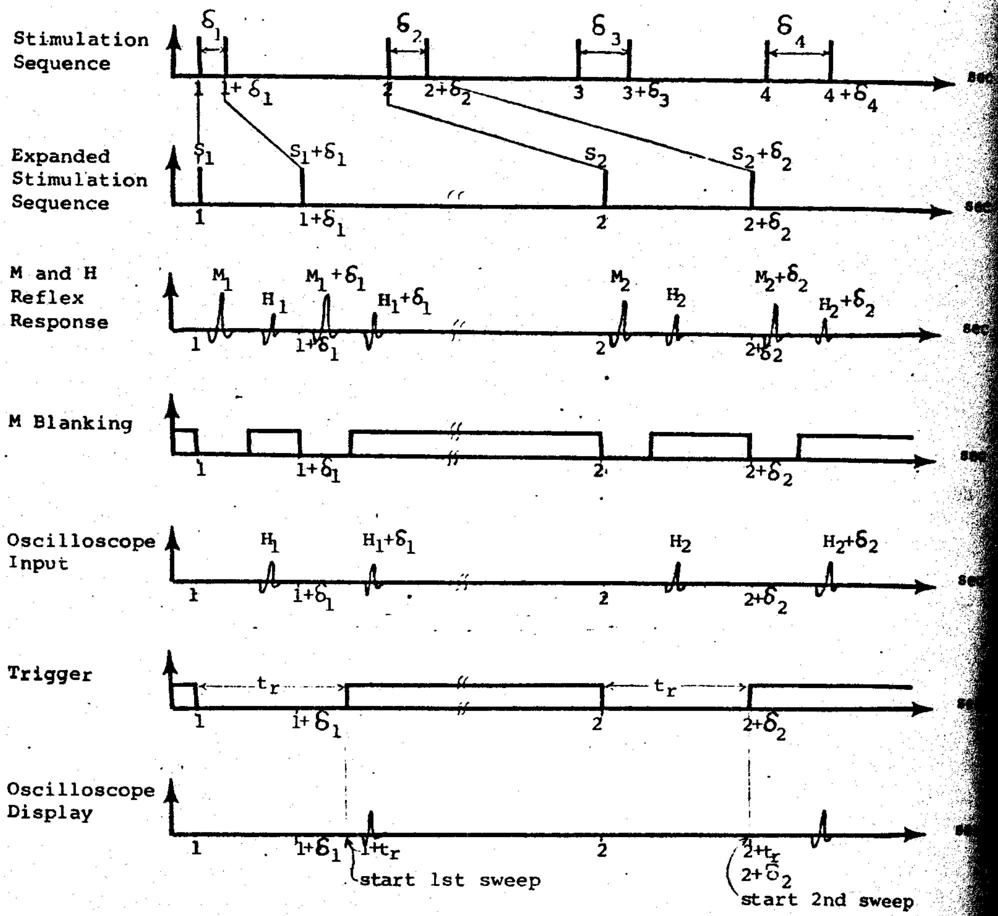
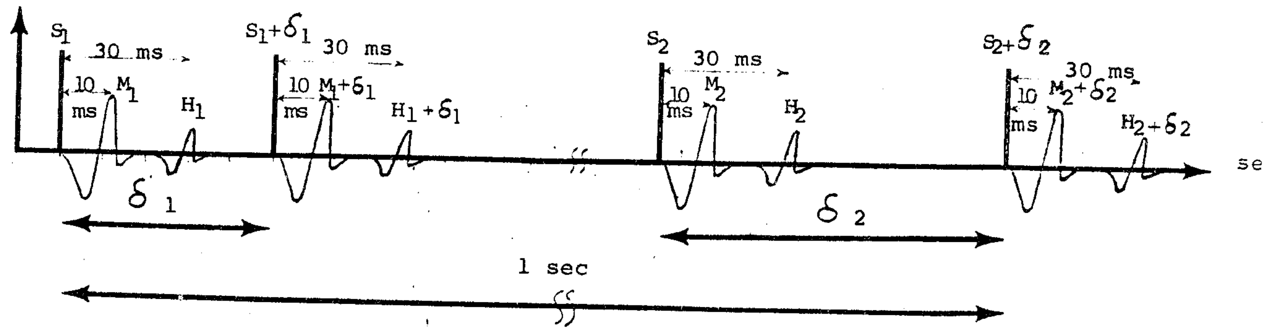


FIGURE 3

STIMULATION & RESPONSE TIMING SEQUENCE

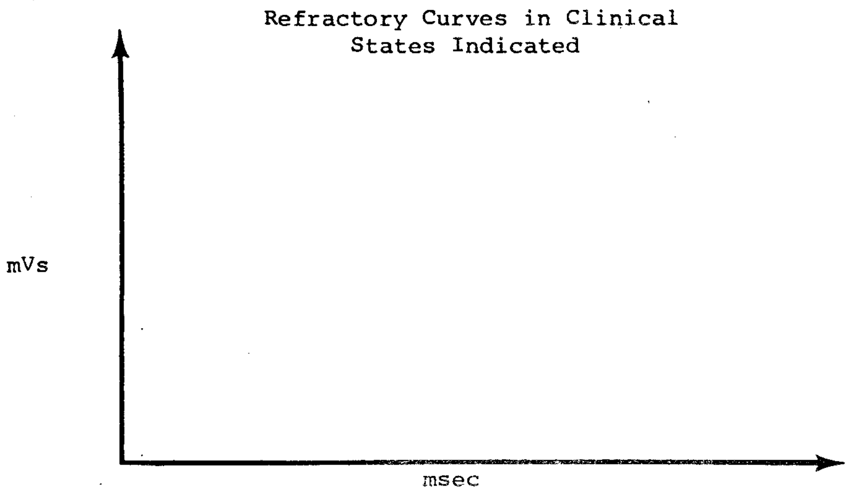


Second H Elicitation Times:

	50 + 10
1 sec	+ 100 + 10
2 sec	+ 150 + 10
3 sec	+ 200 + 10
4 sec	+ 250 + 10
5 sec	+ 300 + 10
6 sec	+ 350 + 10
7 sec	+ 400 + 10
8 sec	+ 450 + 10
9 sec	+ 500 + 10

FIGURE 4

TABULATION OF TIME INTERVALS FOR RESPECTIVE H REFLEXES


Refractory Curves in Clinical
States Indicated
mVs
msec

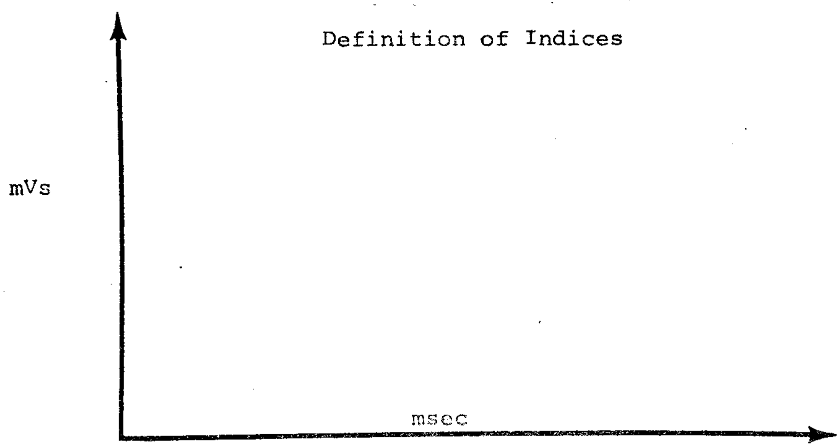

Definition of Indices
mVs
msec

FIGURE 5

Reference

1. Illis, L.S., Sedgwick, E.M., Oygar, A.E., Sabbahi Awadalla, M.A.: Dorsal-column stimulation in the rehabilitation of patients with multiple sclerosis, Lancet: 1383-1386, June, 1976.