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AVERAGERS.

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Whether it be a suitably programmed IRM 360 computer or a $2000 special purpose box, the prime function of a signal averager is the extraction of wanted signals from accompanying 'noise'. Regardless of the sophistication of the averager, they all perform this function in much the same manner and with much the same effectiveness. The differences arise with the number of simultaneous signals that can be handled, the sophistication of any statistical processing that may be carried out on the raw data, the ability to change programs rapidly and the variety of processing programs available. Also of considerable importance are the presence of 'bells and whistles', features which aid the recovery, processing and the display of the data.

It is not tbe purpose of this article to evaluate the averagers currently on the market, since there are quite a variety and more manufacturers are entering the field. Its aim is to give sufficient information to allow the prospective purchaser to intelligently evaluate the capabilities of any averager offered and to choose the instrument which is best suited to the research envisaged. This article rather specifically avoids dealing with the "intelligent oscilloscope" averagers which are currently all minicomputer based and correspondingly flexible and expensive.

WHAT IS AN AVERAGER?

Essentially an averager is an instrument designed for the real time extraction of repetitive stimulus-locked signals from extraneous 'noise' (which may include similar signals but which are not temporally related to the one of interest). The term 'averager* has now become synonymous with any instrument which can perform elementary on-line or real-time statistical analysis of both pulse and analog signals; the analysis programs being 'hardwired' into the instrument and selectable by means of a switch.

Unfortunately, unlike oscilloscopes, averagers are not yet standardized, the terminology and instrument capabilities tend to reflect the background of the manufacturer biomedical, NMR, or nuclear particle analysis and thus similar computing procedures and instrument characteristics tend to be referred to by a variety of terms. These will be referred to under the relevant sections.

ANALYSIS PROGRAMS AVERAGING

This is probably the mode most familiar to the biological scientist. Analog signal averaging has a long history, probably being first performed photographically by superimposing oscilloscope sweeps on a single photographic record. This resulted in a usable but rather unquantifiable average of the co-incident events.

Signals of biological origin appear mixed with a greater or lesser amount of "noise" (extraneous signals) which mask the signal of interest. Sources of noise are legion, but the main ones encountered are likely to be AC line hum, muscle artifact, ongoing EEC or EGG activity or internal noise generated in the amplifiers used to record very low amplitude potentials. In many cases the noise can be many times the amplitude of the signal of interest.

Signal averaging makes use of tbe fact that since noise is essentially random with respect to the signal of interest, algebraic summing of a signal (containing both noise and the signal of interest) over a sufficient number of summing cycles tends to cause the noise to sum to zero, whereas the signal of interest will sum linearly. This is because on the average, the signal polarity will always be the same at any given point in time relative to the triggering signal, whereas the noise can be of either polarity and thus will tend to cancel.

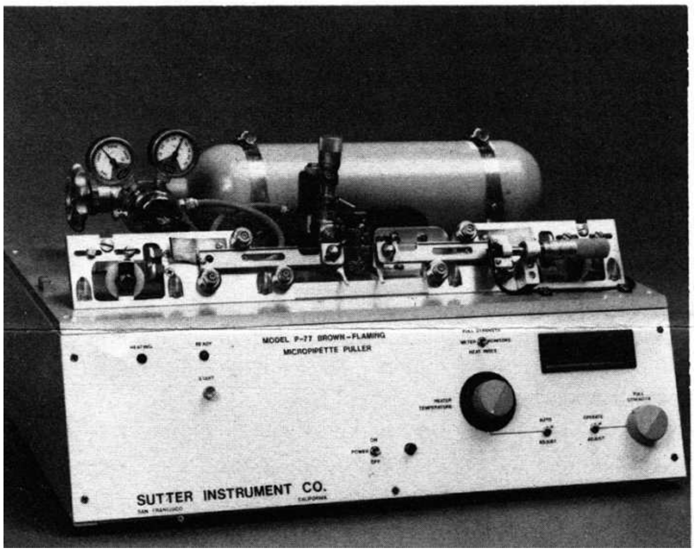
Mathematically speaking, the signal will augment linearly while the noise (here assuming that the noise is 'white' noise) sums as the square root of the number of averaging sweeps ANoise cc \/N~

Thus after 100 sweeps the signal is 100 times larger, while the noise has increased only 10 times resulting in a 10:1 signal to noise enhancement. The actual degree of noise reduction obtained will, in reality, depend on the nature of the noise signals encountered and the degree to which the underlying signals are in fact identical to each other.

Co-incidence is perhaps the key word in most forms of statistical data analysis, since randomly occurring events cannot be processed unless they have an invar-ient time relationship to some signal or event which can be used to trigger the averaging process. Some examples which may be cited to illustrate this would be averaging changes in peripheral blood flow, as detected with a plethysmograph and synchronised to QRS complex of the EKG; or click-evoked brainstem responses and, in the non-biological field, analysis of shock-induced vibration.

An averaging computer can also be considered in another way as a filter whose band pass characteristics "adapt" to pass only the recurring signal of interest, the selectivity of the filter increasing with increasing sample size. (Ref 1)

(Continued on page 2)



MODEL P-77 BROWN-FLAMING TYPE MICRO-ELECTRODE PULLER

With this puller, electrodes with tip diameters less than 0.1 Micron can be consistently and reliably pulled. In addition to very small tip diameters, electrodes as short as 6 millimeters in length (taper) are produced. This combination of characteristics provides a fine-tipped, stiff electrode for penetration of small cells. The electrodes produced on this machine lend themselves to beveling because of their stiffness. They also may be produced in lengths varying from six millimeters through thirteen millimeters, with little or no change in tip diameter. Electrodes produced on this machine have a gradual taper near the tip which facilitates holding cells after penetration. Other secondary benefits are lowered tip resistance, due to the short taper length "and" decreased capacitive coupling in two-barreled electrodes pulled on this machine.

The puller operates on the principle of rapidly cooling the electrode heater to produce electrode lengths shorter than conventional pullers capable of pulling fine tips. Two symmetrical electrodes can be pulled each time. Precise control of heater current, pull strength, air flow and timing sequence provide unequaled consistency in electrodes produced. Platinum replacement heater coils for the #P-77 are available in the following widths, 1,5mm, 2mm, (standard) and 2.5mm.

RAT ALIGNMENT TOOL

Several laboratory manuals recommend a bregma reference system as the variability of the bregma with respect to the brain was found to be less than that of the auditory meatus. In some atlases, the anterior-posterior coordinates are given using only the ear bar reference system, however conversion to the bregma reference system can be made by easily.

The alignment tool will be shown at the Neuroscience meeting this November.

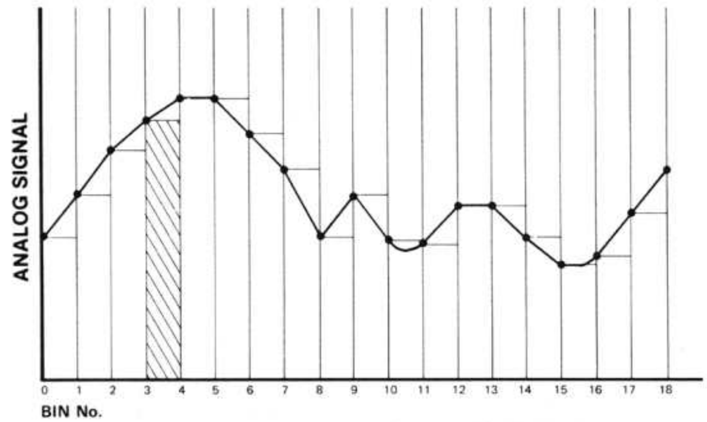


FIGURE 1

Continued from Page 1

HOW DOES IT WORK?

To the author's understanding, all averagers currently on the market use digital techniques to perform the averaging operation and reconvert the digitised data to analog form for display.

Fig. 1 illustrates the sampling process operation on an analog wave form. As the analog-digital converter acts as a sample and hold circuit, the value generated at the sample time (vertical lines) remains constant for the bin duration (shaded rectangles).

All averagers sample (or take time slices, Fig 1}of the analog signal; each sequential slice being processed in sequential memory addresses. The temporal resolution available and hence the temporal fidelity of the reconstructed signal depends on the fineness of the slicing, the number or memory addresses or bins available and the length of signal record which must be averaged.

Fig. 2. Simplified block diagram of a signal averager. The heavy lines represent digital signal data paths.

On initiation of the averaging sweep, the incoming signal is sampled, digitized by an analog to digital converter (ADC fig. 2), and the digital signal is summed, using a binary adder, to the digital word already present in the first memory location or bin (in this case it will be 0). The resultant sum is then written back into the same memory bin. The averager then addresses the next memory location and the above process is repeated and so on, until all memory locations have been processed (1024 or 21(I locations in our example).

With the next trigger signal this entire process is repeated. After a sufficient number of averaging sweeps have been carried out the averager can be set into the readout or display mode. In this mode, accumulation of data is stopped and the binary memory contents are read out via a digital to analog converter (DAC) to produce an analog reconstruction of the averaged signal for oscilloscope display or plotter readout.

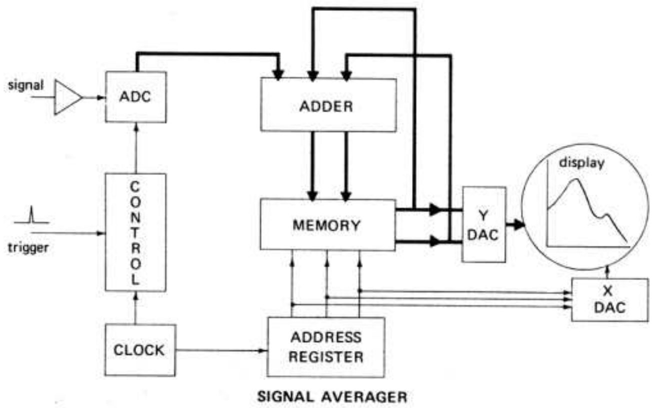


FIGURE 2

Since *time synchrony* with the stimulus and *repeatable sweep duration* are of utmost importance in order to prevent time jitter from 'blurring' the averaged signal, all but the cheapest averagers use crystal oscillator-controlled time bases.

BASIC AVERAGER FUNCTIONAL BLOCKS

Time Base = Address duration, bin width, dwell time per address, total sweep time per. ... .addresses, etc. For biological studies the address duration requirements vary from 5μs (for analysis of single action potentials) to 100 ms per bin for slow phenomena. With a IK (1024 bin) memory, this represents a range from 5.12 ms to 102.4 seconds for total sweep duration and shorter times for smaller memory segments. As it is cheap to add additional slow sweep speeds, manufacturers generally do so, however their utility is questionable.

MEMORY-SIZE AND ORGANIZATION

The now discontinued CAT 400 and Nuclear Chicago 1700 averagers had 400-address memories. The memory used was the expensive ferrite core variety and the 400 addresses represented the smallest usable memory size which was compatible with 4 channel operation. Modern averagers, taking advantage of cheap semiconductor memories employ 1024 address as standard and some have 2K (2048) or 4K (4069) address memories. For averagers this increased memory size results in greater temporal resolution or increased record length.

In the pulse counting modes of operation, such large memory sizes can be a decided nuisance as will be explained later.

In some single channel averagers and in all multichannel models the memory can be subdivided into halves or quarters (quadrants). In multichannel operation the different input signals are sampled sequentially, multiplexed by the ADC and the resulting digital words routed to the appropriate memory sections, thus allowing 2 or 4 channels of data to be processed simultaneously.

Some single and multichannel averagers have the ability to address memory blocks sequentially so as to allow the averaging of the responses from one region to stimuli sequentially delivered to two or more sites. One example of this would be the recording of the

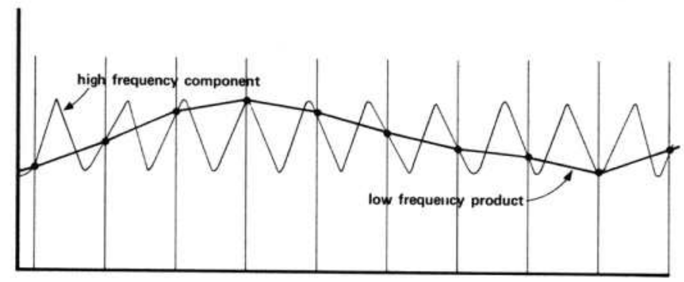


FIGURE 3

evoked cortical potentials resulting from stimulation of, say, four peripheral nerve trunks.

This memory addressing mode also permits "split half" averaging a technique for evaluating the effects of random noise on the signal. (Ref. 1).

Multichannel averaging does carry a penalty in that temporal resolution is reduced, since any one input channel will be sampled at half or quarter the single channel rate, but unless the memory is small (say 400 points) this is of no consequence for most applications.

MEMORY WORD SIZE

Each memory address represents a digital (usually binary) word which may be as small as 8 bits (rarely) or as large as 24 bits. The memory word size chosen depends on a number of considerations: a) the ADC resolution, b) the maximum expected number of full-scale amplitude signals that you anticipate and c) whether the averager boasts integration capacity or logarithmic display (only the most expensive varieties).

Conventionally the input signal levels are set so that the ADC sees a voltage of half its input range, so as to prevent clipping of noisy signals. For an 8 bit ADC this means an average 7 bit output word length. If our contemplated averager has a 16 bit memory word length, this gives us 167 = 9 bits or 512 averaging sweeps before the memory word size will be exceeded and overflow occurs. If the signal is very noisy, as it would be to warrant that many averaging sweeps, then due to the removal of the noise signal by the averaging process the actual number of sweeps that could be averaged could well exceed 1000 before overflow.

Thus a 16 bit memory word length is adequate for an averager employing an 8 bit ADC, and 20 bits for a 10 bit ADC: word sizes in excess of this are largely a wasted and expensive resource in most cases.

ADC RESOLUTION

Generally speaking the longer the ADC word length required the slower must be the dwell time per address and hence the sweep speed, to permit the data conversion to be completed before the averager addresses the next bin. A modern 8 bit ADC has a conversion time of 2.5 μs or less, which gives sufficient resolution (1 part in 256) and is quite fast enough for most biological applications. The more elaborate averagers will often give a choice between slow speed and high resolution (10 bit) or high speed and low resolution (6 bit) depending on the application.

HISTOGRAM MODES

While the averaging of analog waveforms is the most frequently considered aspect of averager use, for situations in which spike train behavior is of interest, the pulse analysis modes constitute a number of extremely valuable functions.

Two basic pulse analysis modes are provided by the majority of averagers available.

(1) Post stimulus time intervals histogram (PSTH or multiscaler). In this mode the averager acts as a simple totalizing counter, summing the number of events (nerve spikes, pulses) that occur during the dwell period for each bin; the memory addressing sequence is the same as for averaging and is triggered by some external synchronizing event. The resultant display is a histogram which constitutes a plot of the probability of the occurrence of an event at any given time following a stimulus. Its nearest equivalent would be a raster display or 'dot-gram' except that unlike the latter, the data is summed and the details of each individual sweep are lost; the trade-off being the compactness, ease of interpretation and comparison and the ability to perform other manipulations, such as integration, on the PSTH records.

INTERVAL HISTOGRAMS (IH)

In this analysis mode the interval distribution between sequential pulses (the interval probability function) is generated. IH analysis is a free running analysis (i.e. not triggered by an external stimulus). Each successive impulse triggers the acquisition sweep and the arrival of the next impulse adds a count of 1 to the memory location corresponding to the time of occurrence; resets the sweep and starts it running again.

IH analysis is valuable for searching for periodicity or pulse pairing in spontaneously firing cells and for observing subtle changes in average frequency of cell firing following some experimental maneuver. Whereas PSTH analysis can usually be run simultaneously with conventional averaging in a multi-channel averager, IH analysis cannot, since its time-base requirements are incompatible.

LATENCY HISTOGRAM (LH)

This function is not generally found but can often be 'jury-rigged' in on many averagers. LH analysis is similar to the PSTH mode, except that on the arrival of the first data pulse following initiation of the sweep by an external trigger pulse, one count is loaded into the appropriate memory location and the sweep is reset until the next stimulus trigger restarts it. LH prevents spike bursts which follow a stimulus from obscuring the latency distribution pattern of the response.

OTHER AVERAGING MODES

There are, in addition to the simple additive averaging modes described above, a number of other modes which have a greater or lesser degree of utility, and all of which cost more to incorporate into an instrument. Auto and cross correllation will not be considered in this article.

TRUE AVERAGING

In additive averaging the size of the displayed signal grows linearly with the increasing number of sweeps performed until the display capabilities are exceeded and 'roll-over' occurs (which can be corrected by the use of a 'display scale control'),

This can be inconvenient in some situations where it is important to be able to monitor the changes in the averaged response as analysis proceeds, or where an automatically calibrated amplitude display is required.

In the true average mode, the displayed signal does not change in amplitude, it merely becomes clearer and more noise free. However most averagers which claim to have true averaging capability perform the amplitude correction after the analysis is complete and then display the corrected results. However unless one is not satisfied with having the number of acquisition sweeps performed limited to powers of 2 (i.e. 2,4,8..... 64,128,256...) in which case the display scale control, when set to the number of sweeps performed will generate a true average; the automatic 'post-hoc' true averaging system is probably of limited value.

EXPONENTIAL OR WEIGHTED AVERAGING

In this mode, which can be considered a 'look-see' function rather than a true analysis mode, the contribution of the preceeding sweeps to the displayed 'average' can be altered by means of user selected scaling factors, thereby producing a 'running average' of the signal waveform while removing minor noise fluctuations. Its main value is for looking at slow changes in signal waveform such as those which would be encountered when passing a microelectrode through a stimulus activated brain locus in an attempt to localise the electrode position.

CAUTIONS AND SOURCES OF ERROR

Since signal averaging is a sampling process (the input signal is sampled once per bin dwell time), it is subject to the same constraints and sources of error that plague any sampling system.

ALIASING (OR FREQUENCY FOLDING)

This term refers to the fact that if the sampling frequency is too low, one can generate spurious low frequency signals from high frequency signal components. Aliasing (or frequency folding) is illustrated in Fig. 3. The input signal, (high frequency component) is sampled by the ADC at the times indicated by the vertical lines and it can be seen that the resultant sample points also describe the wave form of a lower frequency signal, resulting in an erroneous display.

Provided that the sampling rate is at least twice the maximum significant signal frequency component, this problem will disappear (i.e. for a 50 μs/address sweep speed, the maximum frequency component of the input signal must be no higher than 10 KHz). Thus prefiltering of the analog input signal eliminates the aliasing problem while at the same time, has the added benefit of reducing the number of sweeps required to attain a desired degree of signal to noise improvement. Thus the upper frequency limits of the signal should be no higher than that required to ensure good fidelity of the expected waveform.

INTERNAL NOISE

Inherent in the digitizing process is the potential for producing noise, unrelated to the signal noise, and this generates a theoretical limit as to the degree of noise reduction possible (about 60 dB). It is unlikely however, that digitizing noise will constitute a problem unless the signal of interest is a very small perturbation of the baseline and the averager has a logarithmic display.

PULSE SPREAD AND DEAD TIME

When operating in the pulse modes, especially when performing PSTH's or IH's on slowly or erratically firing cells, one encounters the problem of having too few pulses distributed over too many address bins the resultant display being a sprinkling of bins containing 1's and 2's and thus being almost uninterpretable. This is one of the problems associated with having too many memory addresses. The only solution is to 'lump' the counts into fewer bins by running at a much slower speed and in one half or one quarter of the memory space if possible. This is one region where the older 4x100 address averagers had advantages.

Dead time problems are encountered when the averager is unable to accept data pulses. This can occur when in the pulse mode, during part of each address dwell period, when the averager is in a 'write' or 'clear' internal logic state. The better quality averagers have a data buffer which stores the incoming pulses and is interrogated and cleared once for each address which eliminates this problem. Dead time problems can result in loss of data or the inability to reproduce recorded data consistently.

INSUFFICIENT READOUT SENSITIVITY

Some averagers do not allow the first bit of memory to be read out or displayed, presumably to mask excessive digitizing noise. For averaging this does not make much of a difference, but in the histogram modes it results in the loss of data in all addresses containing only 1 count, which can be quite serious.

BELLS AND WHISTLES

Any device or feature which makes the operation of the averager more convenient or increases its utility should be seriously considered by the prospective averager purchaser (often their presence outweighs other omissions).

BUILT-IN OSCILLOSCOPE

I would rate this rather highly unless you have an excess of oscilloscopes or an NSF grant. Since the integral oscilloscope is not a general purpose instrument, its inclusion should cost considerably less than would purchasing a separate laboratory instrument. An averager containing an oscilloscope will have a higher degree of utility in many situations since it is self contained and can be trotted around from one location to another should the need arise (i.e. teaching or clinical use). Since the integral oscilloscope is used for the display and monitoring of the functioning of the averager, it need not be a premium display and considerable cost savings are possible by purchasing averagers which bave a display which is adequate for the intended use.

CURSOR (OR BUG)

Usually associated with built in oscilloscopes on many averagers, the cursor is an intensified portion of the trace which may be shifted from right to left by means of a front panel control. Associated with the cursor is a read out display which displays the address and in most cases, the normalized amplitude of the selected point as well as serving as a sweep counter. This is a very useful feature since it allows the user to directly digitize and record points of interest in the displayed record without the necessity of plotting out the record each time. A variety of other options such as a selected data-point printer can be associated with the cursor.

PRESET SWEEP COUNTER

Included on virtually all averagers, this allows the user to stop the averager automatically after a preset number of averaging sweeps have been performed in the IH mode, 'after a preset number of pulses have been processed. The preset steps are usually scaled in increments of powers of two. The contents of the sweep counter are usually displayed by a digital display or by the cursor display.

TRIGGER CAPABILITIES

Averagers should be capable of being triggered by a variety of sources, ranging from digital pulses to analog signals. To this end the averager should be equipped with at least 2 trigger channels, an external trigger (which usually initiates averaging sweeps) and at least 1 internal trigger channel, usually associated with the input amplifier. The trigger polarity and threshold should be adjustable (although this latter need only be a fairly coarse control) to accommodate signals arising from a wide variety of sources. The trigger circuit should exhibit some degree of hysteresis or 'snap-action' to reduce multiple triggering on noisy signals. The ability to select and route various trigger sources is an advantage.

SYNCHRONIZING SIGNALS

Often it is desirable to have the averager initiate the test stimulus after some preset delay after the start of the averaging sweep. A pulse is generated at the 64th or 128th address and is available at the rear of the instrument. For those averagers capable of operating in the 2 or 4 block serial mode, outputs corresponding to the start of each memory block are usually available.

PREANALYSIS TIME DELAY

Should it be necessary to average a portion of the signal occurring some time after the stimulus (say, to avoid an artifact or a fast component of a response) a pre-analysis delay circuit which delays the initiation of the sweep until a preset time has elapsed is used. Rather useful in neurophysiology but with high resolution memories (1024+ addresses) probably not essential.

POST ANALYSIS DELAY

This is a preset delay which follows completion of a sweep during which time the averager will be unresponsive to incoming trigger signals. This is useful when one desires to sample responses from a train of stimuli, or when the averager is used in the self triggered mode, when this delay will establish the intervals between sweeps. Probably not all that useful in electrophysiology since the averager is seldom used as the system timer. While on this point, in this day of integrated circuits, a few dollars spent on fabricating one's own monostable delays or digital divider chains (each one chip) can save literally thousands of dollars in the purchase of an instrument since a few of the enticing 'bells and whistles' can be constructed in the laboratory.

READOUT CONTROLS

One thing that is liable to drive a busy researcher to perform unmentionable acts to an averager is the lack of independent controls governing plotter readout rate. In cheaper averagers, the time-base controls the readout speed (plot rate) as well, necessitating the user to switch back and forth between two time-base settings for each block of data which must be averaged and plotted out. Needless to say, this results in large amounts of lost data when working under pressure. The plotter output speed MUST BE INDEPENDENT of the main timebase so that plotting becomes a simple matter of pushing a button,

While on this point, a penlift signal activated by the plot command is also necessary unless one appreciates dark spidery lines slashing through critical and never-to-be duplicated data plots.

Some of the more elaborate averagers have the plot speed vary automatically as a function of the range between adjacent points. This results in optimum plotting under all circumstances, but is correspondingly more complex and expensive.

LIVE DISPLAY

Live display indicates that the averager, when not actually processing data, automatically switches into the display mode, allowing the user to continually observe the averaging procedure and the partial results, even though averaging sweeps are being generated once every 10 seconds, It is particularly useful in the histogram modes, and I would consider it an essential feature of any averager. In some of the newer microprocessor based averagers the display is lost when processing rapidly recurring responses.

ARTIFACT REJECTION

Usually found only on clinical averagers, artifact rejection usually implies that one entire sweep of digitized data is stored in a buffer memory. If this signal exceeds preset limits either as (both positive and negative) this is taken as evidence that an artifact has appeared in the input signal, the stored response is not added to the averager memory and an additional average sweep is performed to compensate for each skipped response. Very useful when the signal is sometimes obliterated by a noise pulse, EMG spike or movement artifact. However it is expensive as it either requires an additional memory or else the averager has to 'steal' half of the memory to act as a buffer; thus sacrificing resolution and other modes of operation.

INTEGRATION / DIFFERENTIATION

Found on few averagers. Integration is particularly useful in the histogram mode as it allows the user to totalize the number of responses (nerve spikes etc.) contained within the response; the totals at any given latency and the contribution of each segment of the response to the entire response. Integration is performed by adding the contents of each bin to the succeeding bin, and the integrated response usually must be divided by a constant if memory overflow is to be avoided.

Differentiation is the converse, in that the difference between successive bins is stored.

ABILITY TO INTERFACE TELETYPES AND PRINTERS

The present speed and/or expense of most low cost printers would not seem to make them adequate or justifiable peripherals for an averager. The printing speed of the standard teletype would make the printing out of 1024 addresses and data a painfully and prohibitively slow (41 min) procedure (as well as being noisy). The use of x-y plotters combined with the intelligent use of a cursor facility is far better and faster. If a dump of the memory contents is required, then other routes such as cassette or floppy disk memories which in turn could drive the printing peripherals or load into an off-line computer would be more suitable. Such devices would reduce the memory dump time to almost inconsequential durations.

To interface to a teletype the averager must be RS232 compatible and generate serial ASCII data. For other systems parallel binary or BCD outputs must be available along with the appropriate 'handshake' lines (data ready, next address etc.).

INTEGRAL MICROPROCESSOR (AS OPPOSED TO A BUILT-IN MINI-COMPUTER)

At the moment this is a rather difficult area to advise on since the realm of possibilities is literally changing daily. At the present, (Dec. 1977) the available microprocessors which would be economically suitable for incorporation into an averager to perform all the logical functions are just not fast enough. A hybrid arrangement wherein the microprocessor performs the "housekeeping' functions and the data processing itself is by discrete logic is more feasible, but I know of no manufacturer pursuing this approach. Averagers currently on the market which are microprocessor based do have a number of limitations, but within the next year or so we should see some quite sophisticated designs appear.

Ideally the inclusion of an integral microprocessor could open the way to a host of data manipulations which heretofore were in the realm of mini computer based systems. One other advantage of microprocessors, theoretically at least, is that their internal programs can be updated merely by changing a 'Read Only Memory' chip.

Unfortunately, in this field, as in any other, the technology is advancing at a far faster pace than the user's capacity to employ these benefits and these capabilities seldom get much use purchasers' imaginations and desires often far exceed their real needs and capacities.

COMPUTER COMPATIBILITY

Most of the more elaborate (and more expensive) averagers (Nicolet 1070, Traycor Northern NS 575A, 570 etc.), have considerable interfacing capabilities permitting them to function as fast, real-time analog and pulse interfaces with a minicomputer. Unfortunately some cost as much as the minicomputer itself, so the relative value of this capability must be considered carefully. If lower cost averagers were available with the same i./o flexibility then such averagers would make a far superior substitute for the laboratory interfaces supplied by minicomputer manufacturers.

SPECIAL PURPOSE AVERAGERS VS MINICOMPUTERS

Why have a hard wired, fixed program averager when a PDP11 or a Nova can perform much the same tasks? Flexibility, simplicity of operation, speed of operation and cost would seem to be the main reasons.

While a laboratory mini can perform all the functions of an averager, it can only do so at the cost of a considerable amount of software development time, interface construction and debugging, which unless one has a reasonably sophisticated laboratory computer and backup resources, will cost considerably more than the averager it displaces. Additionally, data digitizing time is often considerably slower than for a comparable hardwire averager, which can restrict usefulness. Having 3 or 4 analysis programs switch selectable allows the user to readily change programs in seconds or to run two programs simultaneously (e.g. PSTH and Averaging). The necessity of reloading programs from disk or paper tape whenever a program change is needed is also eliminated. Besides the averager is completely selfcontained, generally unaffected by the in-evituble 'crashes' which wreck the best conceived computer system and can be moved about as required with perhaps only an X-Y plotter as a peripheral. Granted an averager cannot perform the types of statistical analysis that a computer can, nor can it format the data in the variety of grant agency impressing ways that is possible with a applications where an averager excells, such sophistication is seldom warranted. Where sophistication is desired however, a full scale minicomputer or a minicomputer based averager system such as the Tracor Northern TN 1500 series among others, would be indicated.

CHECK-LIST OF THINGS TO LOOK FOR. OPERATING CONVENIENCE

Not only does an averager have to perform the required analysis, but it must also be easy to use.

Averagers, even the varieties not intended for rack mounting, often end up in racks, thus it is important that controls that are needed in normal operation (such as program selector) are not at the rear of the instrument. CRT intensity and focus controls can be, as there should be little need to adjust them.

The need for an independently controllable plot rate control has been already stressed. Multi-button erase schemes are probably not all that efficient in defeating Murphy Effects, since the human psyche can devise many reflex techniques of obliterating unique data. Ideally, clearing the preset counter and the memory should be possible with one button push, start averaging with another and plot-out by yet another. Display should be automatic. The fewer controls that have to be manipulated to shift from data acquisition to readout, the better.

Plug-in modules which essentially govern the analysis program that can be performed, are a touchy point. On one hand they (theoretically at least) permit upgrading of the instrument, but on the other, they can be a decided nuisance especially if you must carry out simultaneous histogram and analog analysis on the data, each requiring separate plug ins. In addition, it is usually necessary to shut down the averager to change modules, which can result in loss of data.

REPAIRABILITY

Most if not all averagers require that the factory or agent service them, in fact it is often well-nigh impossible to obtain schematics for them. Check out the local agent's reputation before commiting yourself to purchasing an instrument. The name of a couple of averager manufacturers is mud in some parts of US and Canada for this reason.

CAPABILITIES

Whereas an elaborate piece of equipment can be a very gratifying toy to possess (and you don't even have to join the Army) it seems that very few averagers are employed to anything like their potentials. Employ the KISS principle (Keep It Simple, Stupid) in evaluating a putative averager (or for that matter any piece of apparatus). You will discover upon looking around you that a great deal of money has been spent by your colleagues because of some esoteric feature cunningly designed into a piece of equipment by the manufacturer, simply on the grounds that 'it might be useful somedav' and it has never been used.

REFERENCES

1) Principles of Neurobiological Signal Analysis by E. M. Glaser and D. S. Ruchkin. Academic Press 1976.

Interested persons should try and obtain the detailed booklets which are available from most of the bigger averager manufacturers which often have lots of very useful information on particular products (as opposed to the glossy brochures).

OTHER USEFUL REFERENCES

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LETTERS

Recently it was brought to my attention that M. M. Patterson ("Rabbit Stereotaxic Techniques") had referred to my book Small Animal Anesthesia in your house organ. This book has been out of print for several years, having been superceded by Veterinary Anesthesia by Lumb and Jones (Lea and Febiger, 1973).

I do appreciate his reference greatly and wanted to point out to him that a more recent reference was available.

William V. Lumb, D.V.M., Ph.D.
Professor and Director
Surgical Laboratory
Colorado State University
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My very extensive experience with urethane I.V. in rabbits has convinced me that it is as close as one can hope to get to an ideal anaesthetic agent for acute procedures. It can even be used for recovery experiments if used properly and the animals are given adequate post-op care but I do not recommend it for such use. Urethane leaves the rabbit with excellent control of his regulatory mechanisms, e.g., panting and ear vasodila-tation in response to even slightly increased body temperature, inhibition of panting, ear vasoconsfriction and shivering in response to cooling (shivering is a bit blunted). The animal responds to pyrogens normally (but the rise in core temperature is less because of general muscle relaxation). One might even go so far as to say that the animal is more normal than normal because it does not show the troublesome "emotional" responses to restraint, such as emotional hypothermia. I have not studied cardiovascular and respiratory responses in detail but know that these are very satisfactory in urethanized animals used for teaching purposes.

There are a few "tricks" to successful use of urethane: (1) it should be high quality stuff if artifacts caused by pyrogen contamination are to be avoided. (2) it should be made up in normal saline not water. In water it can cause haemolysis. My way is to use 20% urethane in isotonic pyrogen-free saline, injected via the marginal ear vein through a #22 or smaller needle (to guard against too-rapid induction and possible respiratory failure tho this is a very slight danger when compared to pentobarfa. The "basic" dose is 1 gm/kg i.e. 5ccs. Supplementation may be necessary after about 10-15 min. as distribution of the drug causes lightening of the anaesthetic level but repeated supplementation is seldom needed because the drug is very long lasting. Used in this way (and taking several minutes to deliver the basic dose) the casualty rate is zero in my experience.

One additional comment: with all things given by the marginal ear vein I find it very desirable to use a "transilluminator", i.e. a flashlight bulb soldered to a couple of leads and held in the fingers that are not holding the ear. This is especially useful with the urethane injections since the stuff causes a lot of damage if injected extravascularly.

Ronald Grant, Ph.D.
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The comments by Dr. Grant on the use of urethane anesthesia in rabbits are very good. I certainly have no argument with them as they come from extended use of the drug. As he points out, urethane is a damaging drug and a lot of post-op care is necessary for recovery. As with many techniques, it is the "tricks" which make the use successful. Such was the case with sodium pen-tobarbital. Dr. Grant's though tfu In ess in sharing his tricks is appreciated and I'm sure will be helpful.

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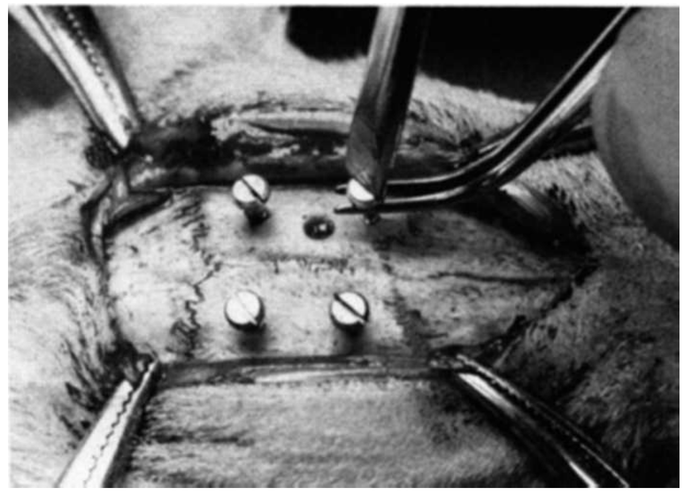
Richard K. Cooley and C. H. Vanderwolf

32. JEWELER'S SCREWS:

Clean the skull of any bleeding from the skull holes and then turn in the jeweler's screws. Care should be taken to turn them in only about 1mm in depth. This is far enough for them to be firmly anchored but not so deep that they will depress the dura and the surface of the brain.



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