## SESSION X: General II

### 10.6: A Transistorized Bio-Tachometer

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BIO-TACHOMETRY is the technique of automatically measuring time relationships of quasi-periodic biological signals.

Due to the nature of direct-writing oscillographs, amplitude is displayed on the Y or vertical axis as a function of time on the X or horizontal axis. Usually, we are primarily interested in the amplitude variations, but often we are interested in interval changes as well. The foregoing physical arrangement is convenient and conventional for the display of waveform amplitudes, but gives rise to difficulty in attempting to reduce visually or quickly reduce the data. This difficulty is caused by the relative inability of the human being to compare many parametric variations if they follow one another in a series arrangement; Figure 1*a*. It is much easier and faster if the variations of interest are turned 90° so that they may be compared side by side, Figure 1*b* and 1c. Knowing this frailty in our built-in, human, data-reduction system, techniques have been developed which automatically perform the conversion from serial variation to a parallel comparison display.

Regardless of what configuration the equipment might eventually take, the basic design approach is essentially the same. That is, the periodic variation is impressed upon a function whose amplitude varies linearly with time; Figure 2. It is thus readily seen that our parameter (variation of time) has been shifted from the horizontal axis to the vertical axis, where ease of comparison is enhanced.

Such instrumentation is not intended to supplant conventional techniques of recording analog bio-parameters such as the EKG. It is, however, intended to supplement these conventional methods to allow:

*(1)* Faster data reduction
*(2)* More information from the same signal in "real time."

There are ways of generating a function which varies linearly with time, as is required for a bio-tachometer. It must be remembered, however, that any such function must be capable of being returned to its zero level at any time. This consideration negates approaches such as the motor-driven potentiometer. One successful design has been the use of a simple series *RC* network which is charging to a relatively high potential; Figure 3. The incoming signal is utilized as a trigger to activate a mechanism which discharges the capacitor thus returning the output level to zero. In some cases the charge on the capacitor is merely sampled by another parallel capacitor, and then the network is discharged. Whatever the method, the voltage at any instant is proportional to time elapsed. It is obvious that this method fulfills three predominant design criteria for medical equipment; it is simple, cheap — and it works.

The drawbacks to this simple approach lie in the inherent non-linearity, Figure 3, of *RC* networks, (except over a narrow range). To utilize this design, one must either recalibrate the usual linear graph paper on a direct writer to correct for this non-linearity, or operate the system at a very low level over the relatively linear part of the charging curve.

It was felt that a unit could be designed and constructed which would utilize state of the art developments in electronics and still result in a simple, low-cost, reliable, and linear bio-tachometer. Basically, the design approach uses a 2-transistor ramp generator in a *Miller* integrator configuration. The incoming signal is clipped to remove the negative portions and then amplified to trigger the ramp generator back to its zero state. If the signal is of a sinusoidal nature (such as respiration), instead of periodic spikes, an optional zero-crossing detector can be used first to generate the necessary waveform. A front-panel control adjusts the clipping level in such a manner that lower amplitude signals (which are unwanted and might have a tendency to trigger the unit) are rejected. The resultant linear ramp is coupled from an emitter follower which is part of the integrator circuit. Such an emitter follower coupling has several distinct advantages. It supplies a very low-impedance output which makes signal contamination unlikely; and simultaneously gives a healthy power gain which is capable of driving a typical galvanometer pen motor directly.

The output of this system is a series of sawtooth waveforms whose amplitude is proportional to the time interval between signals. In EGK interval measurements, a *qrs* spike of 1 volt is sufficient to trigger reliably the bio-tachometer. A typical system diagram is shown in Figure 4.

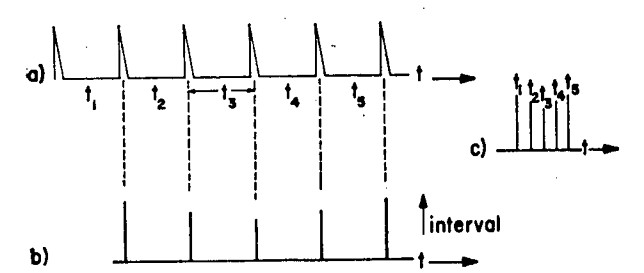


**Figure 1—(*a*) Simulated *QRS* spike of the *EKG*. Note difficulty in discerning difference in intervals $t_1$, $t_2$, etc. (*b*) Interval converted to amplitude. Notice ease in discerning changes. (*c*) Same as (*b*) above, except recording speed is reduced for greater readability.**

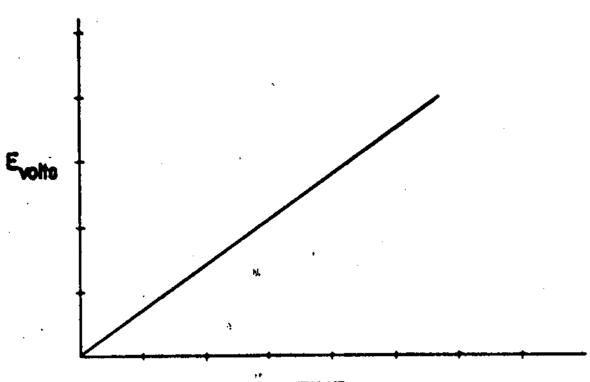


**Figure 2—Linear function of voltage versus time.**

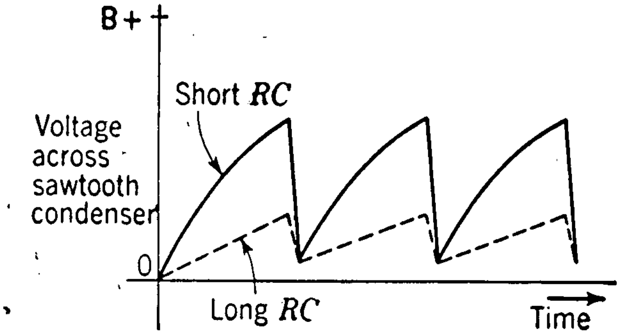


Figure 3—Typical curves showing voltage as a function of time across the capacitor of a series *RC* network. Shorter time constant gives higher amplitude, but poor linearity. Longer time constant allows better linearity, but lower amplitude.

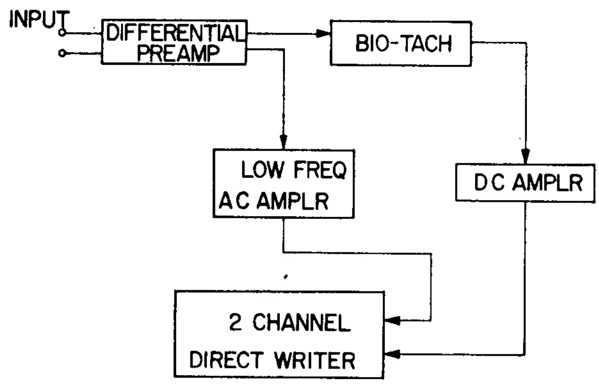


Figure 4—Typical installation block diagram of instrumentation using bio-tachometer. A zero-crossing detector can be inserted in series between preamp and tachometer if necessary.

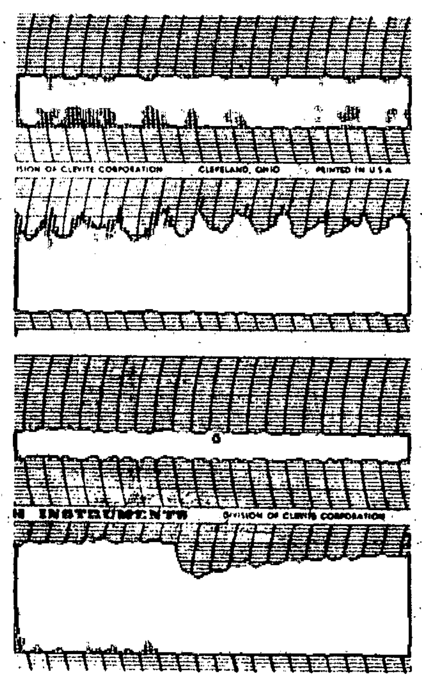

Figure 5—Tracings from system described in Fig. 4. Traces *1, 3* are *EKG*; *2, 4* are tachometer output. Traces *1* and *2* were taken on a resting gopher snake, showing changes in cardiac rate due to respiratory activity (approx. 20 beats/minute over respiratory cycle). Traces *3* and *4* were taken on a Pacific rattlesnake suddenly stimulated by lighting his totally darkened cage. The rattlesnake consistently experienced an increase of 15 to 30 beats per minute upon stimulation.

*(Tracings courtesy H. S. McDonald, Dept. of Zoology, UCLA.)*