A LOW PASS FILTER WITH AMPLIFIER FOR MEASUREMENT OF ACTIVE AND PASSIVE TENSIONS OF SKELETAL MUSCLE IN VITRO

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SUMMARY

When displaying and measuring passive and active twitch tensions developed by skeletal muscle in vitro, the problems of amplification may be resolved by recording two traces. One, recorded at relatively low gain, is used for measurements of twitch tension amplitude. The other, recorded simultaneously, is a modified version of the first trace, in which the voltage signals are passed through a suitably constructed low pass filter, amplified and displayed. This second trace, recorded at relatively high gain, is used for measurements of changes in passive tension and contracture responses of relatively small amplitude.

Pharmacological testing in vitro of preparations of skeletal muscle is a useful procedure in the laboratory screening for suspected malignant hyperpyrexia (Kalow et al., 1970; Ellis et al., 1972; Moulds and Denborough, 1972). If study of the active twitch tension responses is used (Leslie and MacLachlan, 1976), a problem may develop when measuring precisely the tensions displayed on a pen recorder. The problem is basically one of amplification (fig. 1). If the gain of the recording system is set low, one may not be able to detect accurately small, but possibly significant, changes in baseline tension. If the gain is set high so that small changes in baseline tension are appreciated easily, the amplitude of the twitch tension (volts) may exceed the voltage specified for full-scale deflection of the pen, and information on the nature of the twitch tension is lost.

An ideal solution to the problem would be to dissociate the d.c. voltage (the electrical analogue of the passive tension) from the superimposed voltage, that is the electrical analogue of the twitch tension, and to study each, suitably displayed, in isolation. A practical solution is the use of a suitably constructed low pass filter and recording two traces. The one trace recorded at relatively low gain may be used as the display for measurements of the amplitude of twitch tension. The second, derived as a low pass nitrate of the first, recorded at relatively high gain, may be used for the display and measurement of passive tensions and small amplitude contractures.

METHOD

Figure 2 is a circuit-block diagram of the recording apparatus. The part of the circuitry to the left of the diagram is of an operational amplifier arranged as a low pass filter, that to the right is a variable gain d.c. amplifier with voltage offset incorporated. In an initial construction of the filter the values of R1 and...
$R_2$ were set at 22 kΩ and the values of $C_1$ and $C_2$ were 1.0 and 0.47 μF respectively. In practical terms this gave a top cut at about 10 Hz with a roll off of the order of 12 dB per octave. A top cut of 10 Hz was of course insufficient to attenuate markedly those voltages that were the analogue of twitch tension—a prerequisite to the successful use of the proposed solution. Thus in later developments the values of $R$ or $C$, or both, were increased to reduce the top cut frequency to very low values (less than 1 Hz). The gain of the amplifier section was variable, in the range 4.9–14.9, but was usually pre-set at ×5. The voltage offset incorporated in this amplifier was used to “back off” excessive voltages which would themselves have caused the pen ($i/p_1$ (fig. 2)) to deflect past full scale on the recorder.

**RESULTS**

Figure 3 shows records obtained using the apparatus shown diagrammatically in figure 2. The calibration traces illustrate the minute-to-minute stability of the low and high gain outputs respectively: in the short term of minutes, drift is practically non-existent. The two experimental traces, which illustrate typical outputs from the apparatus in action, facilitate measurements of active tension on the one hand (lower trace) and passive or contracture tension on the other hand (upper trace) without compromising precision (or accuracy) of measurements at the expense of incompatible gains or loss of information (fig. 1).

![Filter and Amplifier Diagram](https://via.placeholder.com/150)

**Fig. 2.** Block–circuit diagram of the apparatus. The output from the isometric tension transducer is pre-amplified ($-A$) and displayed, at relatively low gain, on one channel of the chart recorder ($i/p_2$). The output from the pre-amplifier is taken also to the active low pass filter, the output of which is amplified before being displayed, at relatively high gain, on the chart recorder ($i/p_1$). Values of resistance ($R_1 = R_2$) and capacitance ($C_1 = 2 \times C_2$) were chosen to give optimal attenuation, when the filter had a top cut at about 1 Hz. The amplifier on the right of the circuit diagram has a gain variable between 4.9 and 14.9; usually a gain of ×5 was pre-set on this amplifier. (Values of resistors in kΩ). The voltage off-set facility incorporated into the amplifier was used to maintain the pen’s position within the display area of the recording paper.
LOW PASS FILTERING OF TENSION RECORDS

CONCLUSION
This communication has drawn attention to the technical problem in the presentation of certain data from in vitro experiments on skeletal muscle preparations. A practical solution to the problem has been given. Different solutions may be possible, as indeed are further modifications to the present solution, but the present method is inexpensive, easily constructed and works effectively.

For theoretical consideration of the filter circuitry consult Graeme, Tobey and Haelsman (1971).

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REFERENCES

FILTRE PASSE-BAS AVEC AMPLIFICATEUR POUR MESURER LES TENSIONS ACTIVES ET PASSIVES DU MUSCLE STRIE IN VITRO

RESUME
Lorsqu'on expose et mesure les tensions actives et passives de la crispation du muscle strié in vitro, les problèmes d'amplification peuvent être résolus en enregistrant deux traces. L'une, enregistrée à un gain relativement bas, sert à mesurer l'amplitude de la tension de la crispation. L'autre, enregistrée simultanément, est une version modifiée de la première trace dans laquelle les signaux de tension passent au travers d'un filtre passe-bas puis sont...
amplifiés et enregistrés. Cette seconde trace, enregistrée à un gain relativement haut, sert à mesurer les variations de la tension passive et les réactions aux contractions d'une amplitude relativement petite.

EIN FILTER MIT NIEDRIGEM DURCHGANG MIT VERSTÄRKER ZUR MESSUNG AKTIVER UND PASSIVER SPANNUNG IN SKELETTMUSKELN IN VITRO

ZUSAMMENFASSUNG

UN FILTRO PASA-BAJOS CON AMPLIFICADOR PARA MEDIR LAS TENSIONES ACTIVAS Y PASIVAS DE LOS MUSCULOS DEL ESQUELETO IN VITRO

SUMARIO
Cuando se representan y midan las tensiones de contracciones activas y pasivas desarrolladas por el músculo esquelético in vitro, pueden resolverse los problemas de amplificación mediante el registro de dos trazas. Una, registrada con una ganancia relativamente baja, se emplea para mediciones de la amplitud de tensión de contracción. La otra, registrada simultáneamente, es una versión modificada de la primera traza, en la cual las señales de voltaje pasan a través de un filtro pasa-bajos de construcción apropiada, se amplifican y se representan. Esta segunda traza, registrada a una ganancia relativamente elevada, es empleada para medir cambios en tensión pasiva y respuestas de contractura de amplitud relativamente pequeña.