

Development of a Standard Measurement to Predict Subjective Flutter

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Abstract

The old IEEE/ANSI flutter measurement standard did not predict subjective flutter; it also failed to specify several important characteristics of the meter. Comerci proposed a "flutter index" method but it was never adopted. Results of several workers were incorporated in 1962 in a German Standard (DIN) Weighted Peak Flutter measurement. The NAB flutter measurement of 1965 incorporates the frequency weighting of the DIN Standard, and the volume indicator of Comerci. CCIR adopted the DIN method in 1966. Experiments in the U.S.A. comparing the DIN and NAB methods showed the DIN method to be more satisfactory, and this method is incorporated in the new IEEE Standard 193-1971, based on an IEC draft. Circuits to achieve the desired time and frequency responses are given, as well as suppliers of commercial flutter meters and test records to the new standard.

I. Introduction

The problem of meaningful flutter measurements for sound recording equipment is of long standing, and has been well summarized by Comerci [1]. The flutter of a reproducer is best measured by reproducing a constant-wavelength ("flutter free") recording. The speed variations (flutter) of the reproducer frequency modulate the constant-wavelength recording. The flutter meter is a frequency demodulator, a bandpass filter to determine the range of demodulated frequencies that will be measured, and an indicating system (Fig. 1). As Comerci points out, the "flutter" modulation waveform is often a wide-band noise-like signal; because of this, both the frequency response of the filter and the dynamic response of the indicator must be controlled in order to obtain the same reading from flutter meters made by different manufacturers. If the proper time- and frequency-response values are chosen, the readings will not only be

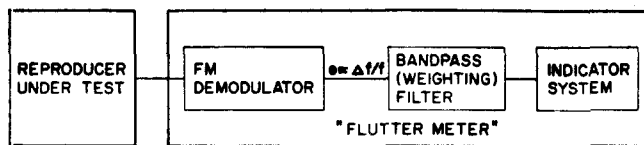


Fig. 1. Block diagram of a flutter measuring system.

consistent from one meter to another, but will also predict the subjective (audible) ranking of the flutter. The term "weighted peak" is used here to indicate that both the time and frequency responses are weighted in order to give readings that will predict the subjective (audible) flutter. (The time-weighted peak rectifier has also been called a "quasi-peak" rectifier.)

The analysis of flutter for design and servicing purposes is not covered in this new standard.

II. Historical Review

A. The Obsolete IEEE/ANSI Standard

The obsolete IEEE and ANSI Standard [2] lacked the necessary frequency- and time-response specifications. The frequency response range was specified as 0.5 to 200 Hz, with no tolerance in this range, and no specified cutoff rate outside of this range. A note allowed a cutoff at 120 Hz "except for the most critical tests." A rectifier characteristic that was "average value" or "between average and rms" was permitted, with no specification of the dynamic (time) response. A note mentioned that "indicating instruments for flutter measurements should be unusually heavily damped, otherwise excessive swings are likely to occur when there is a strong flutter at slow rates, making reading difficult." But different manufacturers' opinions as to just what constitutes "unusually heavily damped" varied considerably, and several flutter meters which met the requirements in the standard, and gave the same reading on a sine-wave calibration test would often give considerably different readings when used on an actual flutter measurement of a reproducer. Thus, a more detailed specification of the frequency and time responses was necessary for standardization.

The particular frequency response and dynamic characteristics not only must be standardized, but should also be chosen so as to give readings which predict the relative disturbing effect of the flutter, as judged by a listening panel. This was mentioned in an appendix entitled "Flutter Index" of the obsolete IEEE Standard, but this measurement was never used widely.

B. The Updated "Flutter Index" Proposal

In the 1950's Comerci studied the possibility of an improved "flutter index" measuring system. He concluded [1] that good agreement between meter readings and subjective listening panel judgments could be obtained by using a frequency-response weighting network peaking at 3 Hz, and falling at about 3 dB per octave above and below this frequency (such a response could be achieved with a passive

Manuscript received October 22, 1971.

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RLC network); and, as the indicator, a Standard Volume Indicator ("vu meter"). The operator was instructed to note the maximum reading of the indicator, since there is often a rather large amount of needle motion ("bobbing" up and down).

This updated flutter index proposal was incorporated in a draft IEEE Standard Proposal in the early 1960's, but the proposal was never completed.

C. The 1962 German Standard

Several studies of measuring means to predict subjective flutter were done in Germany in the 1950's; the result of these studies is summarized in a paper by Belger, which is reprinted (in translation) in this issue of the TRANSACTIONS [3]. This work led to German Standard DIN 45 507, originally issued in 1962 and editorially revised in 1966 [4]. This method uses a frequency-response weighting curve which is the average of a number of curves found by several researchers. It peaks at 4 Hz, and falls 6 dB per octave on either side (this response can be achieved by a pair of simple *RC* networks). The indicator reads the peaks in a controlled time interval, as does Comerci's "flutter index" meter. But, rather than having the operator do the integration visually, the German Standard method does it by using a peak rectifier circuit having an integrating circuit whose charging time constant is about 30 ms, and discharging time constant is about 1 s. This measurement (called in German "quasi-peak") is here called a "weighted peak flutter" measurement. "Weighted peak" here means that both the frequency response and the time response of the indicator are weighted in accordance with psychoacoustically determined values, in order to obtain readings that will predict the subjective (audible) ranking of flutter.

D. The 1965 NAB Standard

When the NAB Magnetic Recording Standards were being rewritten in 1962 to 1964, the flutter measurement committee (C. J. LeBel and the author) considered both Comerci's "flutter index" proposal, and the German Standard. These two methods are quite similar, but unfortunately not identical. The committee did not feel that Comerci's experimental data justified using the more complicated *RLC* weighting network; instead the German Standard frequency response curve which can be realized with simple *RC* networks was chosen.

Both of the methods used indicator systems which read the maximum value of the flutter occurring for intervals of at least 50 to 200 ms, rather than the "unusually heavy damping" of the 1954 IEEE Standard. At the time of the NAB Committee's decision, however, the details of the circuit for the weighted peak method were unavailable, and it was felt undesirable to standardize on a system that might be excessively complicated and expensive. Therefore, the Standard Volume Indicator (as used by Comerci) was chosen

instead. Thus, the "weighted flutter" measurement of the 1965 NAB Standard [5] is a combination of the German Standard frequency-response weighting curve and Comerci's Standard Volume Indicator.

IV. The New IEEE Standard

A. Development

Subsequent field experience with the NAB flutter measurement method showed that it is satisfactory for laboratory purposes where only one carefully trained operator takes all of the flutter readings. He should not only read the meter, but also listen to the tone being fed into the flutter meter, because he then hears that an audible flutter is producing the "bobbing" of the flutter meter needle.

For general purposes, however—with technicians who make only occasional flutter measurements, and with production-line workers etc., none of whom usually listens to the signal—this system has proven unsatisfactory. The meter "bobs" over a 2:1 to 3:1 range, requiring altogether too much operator training and individual interpretation of the pointer motions. For this reason users of the NAB-type flutter meter have demanded that the flutter meter manufacturers add a "slow" or "damped" position on the "NAB" flutter meter. This "damping" (a large capacitor across the meter) completely negates the dynamic requirements of the NAB Standard. Large flutter peaks which are very audible are averaged out. This is thus a completely unsatisfactory solution if the flutter reading is to predict the subjective flutter.

This suggested to the IEEE Committee a reevaluation of the weighted peak indicator used in the German Standard. By this time information about the circuits used for the weighted peak meter was available, as well as experience in the U.S.A. with the design of flutter meters conforming to the German Standard. This experience showed that the circuitry required is in fact rather simple. Also, since the dynamics of the weighted peak meter are largely controlled by the electronic circuitry rather than by the indicating meter (microammeter) itself, the indicator required may be less expensive than the Standard Volume Indicator required in the NAB Standard. Thus, the NAB committee's earlier fears of complication and high cost of the weighted peak meter were proven groundless.

Because of these new findings, a number of "user tests" were performed employing commercially available weighted peak flutter meters according to the German Standard, to find out the following.

- 1) Do the weighted peak meter readings actually predict subjective flutter ranking by listening panels?
- 2) Are the weighted peak meters in fact easier to read than the NAB meters?
- 3) Are the weighted peak meters generally acceptable to recording equipment manufacturers and recording studios in the U.S.A.?

The first test was performed for us by A. L. Seligson of Consumers Union. CU had been using the Comerci "flutter index" method, and had verified that these readings did predict the ranking of equipment for flutter, as measured subjectively by listeners. They compared the weighted peak and "flutter index" readings to judgments by a listening panel, and found that the three readings did agree reasonably well.

The second test—ease of reading—was performed by D. Truax (then of Ampex Quality Audit) who made flutter measurements on a number of tape recorders, using both the NAB and the weighted peak methods. He found that the weighted peak reading was in fact much more easily determined, since the needle is relatively motionless. Several technicians' opinions were asked, and all agreed that the weighted peak reading was much more easily determined, and that they could easily agree on "the" reading by the weighted peak method. Simultaneous NAB readings by several operators were not usually in agreement because of differences in interpretation.

Thirdly, we sent a questionnaire to about 20 U.S.A. tape recorder manufacturers and recording studios who were known to own weighted peak flutter meters. Eleven replies were received, all but one indicating satisfaction with this style of instrument. All but this one said they would be in favor of changing the U.S.A. flutter standard to the "weighted peak" measurement.

Because all of these tests were favorable, a new IEEE Standard "Method of Measurement for Weighted Peak Flutter of Sound Recording and Reproducing Equipment," Standard 193-1971, has been prepared which replaces the 1954 IEEE and ANSI Standard [2]. This new standard is printed in this issue of the TRANSACTIONS [6] and is an adaptation of a draft IEC recommendation [7]. The technical requirements for the weighted peak flutter meter, and the essence of the measuring procedures are the same for the German Standard, the IEC draft, the IEEE Standard, and the current CCIR Standard [8]. Thus, there is an internationally uniform equipment and procedure for weighted peak flutter measurement to predict ranking according to subjective flutter.

B. Circuitry for the Weighted Peak Flutter Meter

The requirements for the weighted peak flutter meter [6, secs. 5 and 6] are given in terms of frequency response and time response, rather than in terms of basic circuit parameters. This is to allow the use of any of several possible circuit realizations. The frequency-response weighting can be *RC* or *RLC*, active or passive. The meter time-response weighting is determined by both the electrical circuit and by the electromechanical parameters of the indicating meter. A few general pointers, however, will assist those first attempting to design equipment to this new standard.

The FM demodulator requires the usual means to avoid interference by amplitude modulation of the signal, and/or

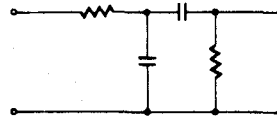


Fig. 2. A simple RC circuit for the frequency-response weighting network.

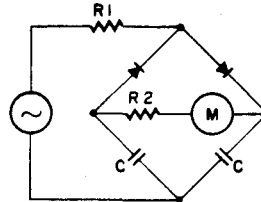


Fig. 3. A simple circuit for the peak-to-peak rectifier, including the necessary time-response weighting constants, $\tau_{chg} = R1 \cdot C$, and $\tau_{dischg} = R2 \cdot C$.

noises added to the signal. Thus, automatic gain control and/or limiters, and signal bandpass (to eliminate out-of-band noise) are usually required. The demodulator may be of any of the FM detectors—pulse counter, slope detector, Foster-Seeley or ratio detector, to name a few of the common circuits.

The frequency weighting response may be achieved by a simple *RC* network as shown in Fig. 2. A further 6 dB per octave slope at low frequencies is required, for the total fall of at least 12 dB per octave prescribed in Fig. 1 of the standard.

The requirement for a peak-to-peak rectifier is easily achieved by using the doubler circuit shown in Fig. 3. (Note that the Standard calls for a peak-to-peak rectifier, but a calibration in terms of one-half this value, that is a *peak*—not peak-to-peak—calibration.)

The time response is influenced by three things: the integrating and differentiating action of the frequency response weighting network; the charge and discharge time constants of the rectifying network; and the speed of the meter movement (easily specified in terms of its mechanical resonance frequency and the overshoot). The usual design procedure is to design the weighting network, choose the meter movement, and then adjust the rectifying network time constants to obtain the desired time response. A somewhat overdamped meter with a resonance frequency of about 2 Hz is appropriate; a meter with Standard Volume Indicator dynamics (resonance frequency, 2.2 Hz; overshoot, 1 to 1.5 percent) also could be used. With such a meter and the standard weighting network response, the charging time constant of the network in Fig. 3, $R1 \cdot C$, will be about 30 ms to give the

required 62 percent response for a 30-ms pulse. The discharge time constant $R2 \cdot C$ will be about 1 s, to give the required fall to 40 percent in 0.9 s. (Note that for the particular test waveform used, the discharge is one capacitor in a series with the meter, rectifier, and source resistances—it is not the two capacitors in series with the meter.)

C. The Test Frequency

Several different test frequencies have been used in the past for flutter measurements. The most common in the U.S.A. was 3000 Hz [2], although 1000 Hz had also been used occasionally. The German standard [4] specified the nearest "preferred frequency" [9], which is 3150 Hz. The CCIR standard [8] and the IEC draft [7] also specified the "preferred frequency" of 3150 Hz.

The actual test frequency used is of little importance to the measurement so long as it is well above the measurement bandwidth (200 Hz) and well below the upper frequency limit of the equipment being measured, which is at least 3000 Hz even for speech-transmission equipment. It is, however, desirable that a standard frequency be chosen so that test records and flutter measuring equipment may be manufactured in a uniform and interchangeable way.

The "preferred frequency" of 3150 Hz was finally chosen by the IEEE Committee for the following reasons.

1) 3150 Hz is the standardized preferred frequency according to both ANSI and international standards, and is presently used internationally for flutter measuring equipment and test records.

2) All presently manufactured "weighted peak flutter meters" either operate at 3150 Hz only, or else operate at both 3150 Hz and 3000 Hz.

3) None of the flutter meters to the old ANSI standard [2] which work at only 3000 Hz are capable of measuring "weighted peak flutter" according to the new standard. Therefore, it does not really matter that they do not operate at 3150 Hz.

Since test records on disks, tapes, and films tend to have an increased flutter with usage (especially if they are improperly used or stored), they need to be replaced occasionally. Thus, 3000-Hz test records may be replaced as they wear out, at no additional cost. In the meanwhile, the "good engineering practices" of the new standard call for the meters to operate properly with test frequencies between 3000 Hz and 3300 Hz (that is, 3150 Hz \pm 5 percent), which allows the use of 3000-Hz records at the lower limit frequency.

D. Commercially Available Weighted Peak Flutter Meters and Test Records Meeting the Requirements of the New Standard

Since the technical requirements given in the new standard for weighted peak flutter meters are identical to those long

established by the German Standard DIN 45 507 (1962 and 1966) [4], existing meters to the German Standard may be used for the measurement under the new IEEE Standard [6].

Some presently manufactured meters are as follows.

Instruments manufactured by 3M Mincom Division, Camarillo, Calif.²

1) Model 8100/8100-W, in the "DIN WTD" position only.

2) Model 8155, Option -01 (DIN) only, in the "WTD" position only.

Instruments distributed by Gotham Audio, New York, N. Y.

1) Models ME-102b and ME-104, in the "fast" ("slow" button out) and "weighted" ("unweighted" button out) positions only.

2) EMT Model 420A in the "damping off" ("damping" button out) and "frequency-response weighted" switch positions only.

Note that all of these meters have push buttons or switches that allow them to be used for flutter measurements that are *not* according to the standards.

Test records with a 3150-Hz signal which may be used for flutter measurements according to the new standard may be obtained for instance from the following companies.

1) Tape records: Ampex Corporation, Redwood City, Calif. The Standard Tape Lab., Oakland, Calif.

2) 16-mm and 35-mm motion picture film records: The Standard Tape Lab., Oakland, Calif.

3) Disk records: Gotham Audio Corp., New York, N. Y.

References

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- [4] *Measuring Equipment for Frequency Variations in Sound Recording Equipment*, German Standard DIN 45 507-1966.
- [5] *Magnetic Tape Recording and Reproducing (Reel-to-Reel)*, Dep. Eng., Nat. Ass. Broadcasters (U.S.A.), 1965. See Secs. 2.13.01 and 2.13.02.
- [6] *Method of Measurement for Weighted Peak Flutter of Sound Recording and Reproducing Equipment*, IEEE Standard 193-1971; ANSI Standard S4.3-1972; reprinted in this issue, pp. 81-88.
- [7] *Method of Measurement of Speed Fluctuations in Sound Recording and Reproducing Equipment*, IEC Draft Recomm., Doc. 60A(CO)12, Jan. 1971.
- [8] *Measurement of Wow and Flutter in Recording Equipment and in Sound Reproduction*, CCIR Recomm. 409-1, 1966 and 409-2, 1970.
- [9] *Preferred Frequencies and Band Numbers for Acoustical Measurements*, ANSI Standard S1.6-1967.

² These instruments now being manufactured by Mincom were formerly manufactured by DMC, which was previously called Micom, previously Bahrs Industries. The Models 8100, 8100-W, and 8155 are functionally identical, no matter which company name is on the panel.