Meters which monitor audio levels are typically one of two varieties: VU (Volume Unit) or PPM (Peak Program Meters). Though both perform the same function, they accomplish the function in very different manners. A VU meter displays the average volume level of an audio signal. A PPM displays the peak volume level of an audio signal. Analogy: The average height of the Himalayan Mountains is 18,000 feet (VU), but Mt. Everest's peak is 29,000+ feet (PPM).

For a steady state sine wave tone, the difference between the average level (VU) and the peak level (PPM) is about 3 dB. But for a complex audio signal (speech or music), the difference between the average level (VU) and the peak level (PPM) can be 10 to 12 dB! This difference between the reading of a VU meter and a PPM is known as the crest factor.

A VU meter and PPM also have different ballistics (acceleration/deceleration rates). If a 1kHz steady state tone is fed into a VU meter, it takes 300 milliseconds (0.300 seconds) for the meter to stabilize. However, the PPM stabilizes within 10 milliseconds (0.010 seconds). As the VU meter displays an average volume of the audio signal, it must "sample" the audio signal over a longer time period than the PPM.

Because of the crest factor and the difference in ballistics, a VU meter and a PPM will display the same speech/music audio signal in very different ways. Therefore, using a steady state tone to align a VU meter with a PPM is not effective unless these differences are taken into consideration.

The VU meter closely corresponds to the level sensing mechanism of the human ear. It provides a useful indication of the subjective loudness of different programs and is very useful when matching levels between programs. But the VU meter does not give an accurate indication of peak signal levels because of its relatively slow ballistics. In practice, a VU meter will under-indicate the peak signal level by 8 to 20 dB.

Here is a rule of thumb when using a steady state tone to align a VU meter with a PPM. When the VU meter indicates "0" (typically a +4 dBm level), the PPM should be set to read 20 dB below its maximum full scale reading. For example, when the VU meter of a Shure FP mixer reads "0", the PPM on a Sony Beta Cam with a "+12" full scale reading should be set to read at "+8". Like any rule of thumb, this one may vary depending on the actual specifications of the products in use.

Note: Meters marked with the symbols "VU" or "PPM" may not actually meet the international standards for such meters. The best advice is to listen critically while recording and not rely solely on meter readings.

Audio meters are a poor, misunderstood lot. In many pieces of equipment they are included seemingly as an afterthought, as a signal presence indicator or just "something to go by" rather than as a true measurement device.

For offline setting of levels (with sine waves), almost any kind of meter will suffice, especially if the meter is built into the device you are setting. "Turn it up until the third LED lights" will still result in a repeatable, if only an arbitrary, level.
able. It can be tempting to use these metering devices that have reasonable accuracy but unknown frequency response, depending on the application. The use of sine waves, or pure tones for set up allows the use of lower-quality meters or digital multimeters without true RMS algorithms to be used. Inexpensive digital meters often read the average value of a signal, but if they assume that the signal is a sine wave (sometimes not a correct assumption), the display can be scaled to "read" RMS values.

Metering, both for calibration and operation (gain riding), is an area where multiple standards coexist. The traditional method of metering/monitoring audio signals was the VU meter. Learning how to "ride" an audio level is very much an acquired skill. It is sometimes difficult to interpret the movement of a VU meter, and instructing operators how to set program levels based on its "readings" can give greatly varying results. If there is a VU meter somewhere in the room, many operators will, almost subconsciously, glance at it occasionally as a sort of "reality check" during a session or show. More often than not, this is due to the lack of faith in the meter that the operator is looking at.

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We have come a long way from the days of the VU meter with an LED to indicate "peak" level. There are metering implementations that give us much more information about the signal than the old VU meter ever could. The trick is to figure out a way to show the most information without the display being cluttered or hard to read and interpret.

As broadcasters work with an expanding number of audio channels (first mono, then stereo, and now even more) it becomes challenging to try to come up with a method to meter and display all of this information in a format that is meaningful, yet still easy to comprehend.

Most audio mixers and engineers are familiar with using a Lissajous, or X-Y display for two-channel systems. But as the number of channels grows to four, five, six, eight or even more, how can that many channels be comprehensively or intuitively monitored? A number of manufacturers have developed displays that can broadly be referred to as "fish finder" displays. This is because of the resemblance of these displays, at least at first glance, to a sonar-type display used by boaters and anglers to find fish and the depth of the water.

The look, as well as the technology, of these displays varies widely and many designers are trying to come up with the best way to accomplish this task. Measurement devices resembling audio meters have been developed for video signals, and any such approach is fair game for development and approval by the marketplace. It will most likely come down to users forming a consensus on the most useful of these displays. The waveform monitor and vectorscope evolved into the de facto standard measurement devices for monitoring video signals.

Many manufacturers are looking for the best way to monitor multichannel audio signals. If you can, the best way to evaluate these meters is to give them a try. Talk it over with your colleagues and see what they think. If you have the opportunity, visit the manufacturer at trade shows or dealer showrooms.

Digital meters mean different things to different people. Because digital audio assigns a value to every audio sample, it is theoretically possible to build a meter that could indicate every single audio sample. Of course, it would take over 65,000 LEDs to build such a meter, and it wouldn't be all that useful. These meters can also have ballistics programmed into the device, so they can be changed from VU to PPM to "true peak" at the programmer's option (and be selected by the operator.) Peak hold is also an option.

Digital meters can be made with different resolutions. An eight-segment LED meter has more resolution than a four-segment LED meter, and less resolution than a 64-segment meter. It is important to remember that these statements alone do not describe the accuracy of the meter at all.

Audio meters are really scientific instruments. But in order for them to be useful in a production environment, they must be easy to use and provide the desired information without the need for time-consuming interpretation. The merger of science and art continues to evolve. Equipment manufacturers are now offering solutions, but they need to have feedback to develop these designs into truly useful tools that broadcasters use in their day-to-day operations.
Audio metering is one of the most confusing and complex aspects of sound recording. Technical Editor Hugh Robjohns answers some of the most common questions on the topic.

There are literally dozens of different audio metering systems in common use around the world — and they often appear to read completely differently when supposedly displaying the same audio signal! However, there are perfectly good reasons why this should be the case and the differences are mainly due to the historical development of the various metering systems and their interpretation. Having said that, not all meters are equal and it's still a case of 'horses for courses' when choosing which system to use in particular applications.

Q What are the meters really for?

All audio material has a certain dynamic range — the difference between the highest and lowest acceptable levels. We typically arrange for the loudest peaks to be below the maximum level which the system can handle and for the quietest signals to be kept well above the noise floor. If signals roam beyond these boundaries then your ears will usually tell you something is wrong, irrespective of whether you are using analogue or digital systems. However, metering can help to make the process of setting optimum signal levels much quicker and easier, warning you of potential problems before they occur.

RTA & Level-history Metering

It is often important to know how the programme level varies in different parts of the frequency spectrum, and this is the role of the real-time spectrum analyser or RTA. Just as with programme level meters, there are many different measuring standards for RTAs covering meter ballistics, numbers and widths of the separate measuring bands, and many other parameters. Another class of meter shows the history of programme levels — how the signal level has changed throughout a track or programme — and there are specialised metering systems which have evolved to provide this data, too.

Beyond the technical considerations of avoiding overloads and maximising signal-to-noise ratio, the majority of level meters found on recorders and consoles are really only intended as an aid to balancing sound levels — the human ear should always be the final arbiter because, self-evidently, if it sounds right it is right! Simply matching peak meter levels between different sources (especially recordings made at different times and in different studios) certainly won't result in a consistent, balanced sound — and I know of several blind audio engineers who can balance and control programme levels better than many sighted engineers without the benefit of level meters at all!

Q What's the difference between VU and PPM meters?

The VU (Volume Unit) meter is amongst the simplest of meter designs, and it has been used since the very beginning of the audio broadcasting and recording industry. It was designed to display an approximation to the RMS voltage level of electrical signals — RMS ('Root Mean Square') voltage is a complicated-sounding engineering measure of the average voltage level of electrical signals. For a sine-wave tone, a VU meter does give a true reading of RMS voltage level, but with complex signals, such as most audio, this approximation is less accurate, and the VU meter will usually read slightly lower than the true RMS value. However, it still provides a useful tool for most practical recording tasks.

Because the VU meter measures 'average' levels, a sustained sound reads much higher than a brief percussive one, even when both sounds have the same maximum voltage level: the reading is dependent on both the amplitude and the duration of peaks in the signal. In addition, the standard VU response and fallback times (around 300 milliseconds each) exaggerate this effect, so transients and percussive sounds barely register at all and can cause unexpected overloads.

VU meters are inherently cheap, though, whether in the form of a moving-coil meter or as a bar-graph of LEDs. This is principally because there is no complex peak-sensing driver circuitry involved — as a consequence, VU meters tend to be used in order to cut costs where there is a requirement for a large number of meters, or where the meter needs only to provide an indication that sound is reaching a particular channel (such as on a multitrack recorder or large console).
Occasionally, you might notice the VU meters on different equipment reacting differently to an identical audio signal, particularly when professional and budget units are used side by side. This is because, though VU meters are supposed to be sensitive to both the positive and negative half-cycles of audio signals, many budget units are sensitive only to one half of the waveform. This can lead to considerable differences between VU readings, as many audio signals are asymmetrical.

'Peak Programme Meters' or PPMs are considerably more expensive than VU meters, partly because of the much more elaborate circuitry and partly because of the precisely defined characteristics of the physical meter itself. Yet even PPM displays aren't designed to catch the very fastest of transient peaks, and are often termed 'quasi-peak' meters for this reason. They only show transients which are sustained for a defined time — the specifications state that 'Type I' meters have an integration time of 5mS, whereas 'Type II' meters have double this figure. The result of this is that the levels of transients will usually exceed the PPM reading by between 4dB to 6dB. This design encourages overall programme levels to be driven slightly higher (giving better signal-to-noise performance) and assumes that overloading the briefest transients will be inaudible — a fairly reasonable assumption in most good analogue audio equipment. The differing integration times of the Type I and II meters simply reflect alternative opinions on the audibility of transient distortion.

PPMs are also characterised by a slow fallback from displayed peaks, which is intended to make it easier to register the peak level visually — Type I meters should take between 1.4 and 2.0 seconds to fall 20dB whereas Type II meters should fall 24dB within 2.5 to 3.1 seconds. Furthermore, Type II meters also incorporate a delay of between 75mS and 150mS before the fallback occurs — effectively a peak-hold condition — which helps reduce eye fatigue.

In an attempt to combine the best aspects of both VU and quasi-peak meters, some bar-graph level displays are available with a VU response shown as a solid bar, accompanied by a floating dot above it which registers the PPM level. This floating dot often has a temporary or permanent hold function to ensure that the maximum peak level is observed.

Q Why do some meters have very different scales to others, and how do they compare?

A variety of different audio metering scales have been developed by different industries in different countries, each of which optimises the display for a specific set of applications. While the VU meter has now become fairly standardised — zero point at +4dBu with a decibel scale ranging non-linearly from 20dB below this point to 3dB above — the PPM meter has a number of recognised scaling systems. Type I PPMs are available in German DIN and Nordic N10 variants, while Type II PPMs can commonly have either a BBC or an EBU version (see the diagram, right, for a comparison of these standards). As a rule of thumb, the scales for Type I meters generally display a considerably greater dynamic range than those of Type II, and their calibration encourages more of the system headroom to be exercised in normal use.

Where multiple meters are used together (such as in stereo or multi-channel systems), each meter's dynamic response must match to within a tenth of a second and their amplitude responses should be within 0.3dB of each other in the critical areas of the meter range. In order to calibrate VU and PPM meters, it's best to use a mid-frequency sine tone (typically 1kHz), as these signals are the most accurately read by meters which are not truly peak-reading.

Q How does all this relate to digital metering?

Unfortunately, the nature of digital systems is such that even the briefest of transient overloads is clearly audible, so neither VU nor PPM metering is suitable. The majority of digital recorders, mixers and converters therefore use true peak-reading meters whose displays are derived from the digital data stream. As these don't rely on analogue level-sensing electronics they can be extremely accurate.

Analogue meters all have a nominal alignment point — the zero reference — with a notional headroom above. The idea is that signal peaks are routinely allowed into the first 8dB or so of this headroom, though peaks of +12dBu will usually start to cause distortion which becomes more and more noticeable with increasing level until clipping occurs, usually at between 18dBu and 22dBu.

Metering And Loudness

Although the VU meter was designed to provide some indication of volume, level meters in general display information about signal voltages rather than their perceived loudness. This is why it is important to realise that meters are only an aid to judging the acoustic balance of audio material. However, there are specialist metering systems designed to
measure and display the absolute loudness of a programme, taking into account the characteristics of human perception. This kind of metering is becoming increasingly important as broadcasting organisations are now transmitting hundreds of channels via satellite, cable and the Internet and it is impossible to monitor all of them acoustically. Also, with the growing use of sophisticated multi-band compressors, it is possible to create audio material which appears completely normal on quasi-peak meters yet sounds extremely loud. This is starting to cause problems at programme junctions and, in the cinema, has lead to an increasing number of complaints about excessive playback volumes. Responsible post-production houses are starting now to monitor and regulate the true perceived loudness of films using special loudness meters. The most familiar programme loudness meter is, probably, the Dorrourhs unit, but Thames Television and the ITC have also come up with a specification for displaying the relative loudness perception of typical audio programme material.

The perception of loudness depends not only on the level of a signal, but also on its frequency and bandwidth — the wider the bandwidth, the louder a signal seems to be, even if its peak level remains constant. The ear is known to be most sensitive around the 2-4kHz region, so signals in this frequency band will sound much louder than low- or high-frequency signals of similar peak level. For example, band-limited 1/3-octave noise signals at 100Hz and 10kHz can be almost 15dB higher in level than noise centred on 4kHz, yet all will be perceived as sounding equally loud!

Digital systems, however, have no headroom above the maximum quantisation level, and therefore a notional headroom must be created by choosing a 'zero' point well below this. Digital meters are scaled such that the maximum quantisation level is denoted as 0dBFS (full scale), so the alignment level is always a negative value below this point.

In Europe 0dBu has been standardised by the EBU to be -18dBFS, in order that a signal peaking in analogue equipment at the top of the EBU-standard PPM scale — and therefore with true peaks at around +16dBu — remains a little below the digital full scale value. Just to be awkward, though, the American SMPTE organisation set their standard for 0dBu at -20dBFS instead...

These calibrations assume uncontrolled source dynamics where unexpected transient peaks might use the full dynamic range available. However, in post-production and mastering situations, where programme levels have been carefully controlled, these standard alignments typically cause most mixes to peak only below -10dBFS. Consequently, there are strong arguments for adopting a different alignment strategy in these circumstances — I generally align 0dBu to -12dBFS for mastering work, for example. However, there is as yet no standard calibration specifically for post-production applications.

Q What is the significance of the 'Over' light on a digital machine?

Over indicators are found on A-D converters, mixing consoles and some digital meters, and are supposed to illuminate when the signal exceeds the maximum quantisation level. In the case of the A-D this is when the analogue input is greater than the available quantisation range and, on a digital console, it is when some signal-processing operation results in a sample value larger than the maximum quantisation level. Both situations are clearly defined, because the excessive source signal can be directly compared with the quantisation level, and are therefore entirely valid situations in which to light the Over indicator.

However, the Over light can often be less meaningful when you are merely metering already-digitised audio without the benefit of the original source as a reference. The only way in which most digital meters can detect overloads in the audio data stream is by watching for consecutive samples with the maximum quantisation value. Commonly, four consecutive maximum-value samples are interpreted as an overload, but some meters include an option for the user to specify this number.

This manner of interpretation is ambiguous, however, because four maximum quantisation values in a row does not necessarily imply an overload. A peak-level low-frequency signal could easily create four maximum-value samples quite legitimately, whereas a high-frequency signal could be severely distorted with just a couple of peak-value samples. Most decent stand-alone meters use oversampling techniques to provide greater accuracy in their calculation of what represents an overload within the digital data stream, but even this is not foolproof. If in doubt, set the Over light to activate with a single full-scale value — even a single peak-value sample means that you're awfully close to overloading.
**REFERENCE LEVEL WITH TEST TONE : -8 dB**

**IDEAL PROGRAM RECORDING LEVEL:**

-2 TO +2  (0 is your target)

**Reference Level with Test Tone:**

-8 dB

**Ideal Program Recording Level:**

-2 TO +2  (0 is your target)

**Note:** Peak reading meters are also found on older Beta & Beta SP cameras. They are LCD meters. When recording a reference level with color bars, record the tone at 0. After recording reference level, re-calibrate camera meter to mixer meter if they are different (example: mixer has VU meter & camera is peak reading, set mixer reference level to 0VU & camera meter to -8 dB. Adjust program recording level using mixer’s metering system.

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**LCD Digital Scale Meter**

**Reference Level with Test Tone:**

-20 dB

**Digital Video**

-20 dB

**Dat & Other Digital Recording Devices**

-18 to -20 dB

**Computer Software Digital Meter**

**Program Level** should Never Hit 0

For broadcast video, peaks should not exceed -10 dB.

Other: Film, Music, Computer etc.

Audio peaks should be recorded @ -8 to -4 dB.

Not to fall below -20 dB
The meters on the Sound Devices 302 mixer can show a combination of Peak and Vu levels at the same time. This is done by pressing the PK/VU button until Vu with a fast returning Peak level indication is selected. When the reference level test tone is activated, the meter reads 0 Vu, and the metering system returns to reading a combination of Vu and Peak when the test tone is shut off. So where do you set your levels? When you calibrate the camera with the 1K test tone on, set the camera’s meters to -20 dBfs. When you record your dialog, peak the levels @ +12dB. This will make your recording levels peak on the camera at @ -10dBfs.