AUDIO LEVELS

EMANUELE COSTANTINI

INTRODUCTION

Audio transmission begun with telephone industry in 1939 inside the Alexander Graham Bell's laboratories. Balanced audio and 600Ω impedance came out with this technology and subsequently in the Radio-TV transmission.
The unit reference was the Power and they used to compare audio power measurements with the reference of 1W on a load of 600Ω.
The result of this ratio is in deciBel wtih the assigned unit dB_m .
The maximum power transmission between the source and the load is when the impedance of the two devices is the same and follow the 600Ω characteristic.

Today the power-matched transmission is replaced by a voltage-based system where the source impedances are kept low.
This ratio is described by the term dB_u (unterminated).
To maintain some continuity with the old dB_m reference we calculate the voltage value achieved dissipating 1mW on a load of 600Ω.

$$\sqrt{\frac{600}{1000}}=0{,}77459$$

rounded to 0,775V.

This value is called Signal Nominal Level, indicated with Ødb_u.

The SOL (Standard Operative Level) or Nominal Level is the used reference electrical level.
Is the value to not exceed with stationary levels used to align the measurement instruments.
The most common professional level is +4dB_u. It means that the stationary voltage level is 4dB greater than the voltage value just described:

$$10^{\frac{4}{20}}\cdot 0{,}775=1{,}2282922$$

rounded to 1,23V.

In the film industry, another common value is +8dB_u.
In general the professional values can be between +3db_u and +11dB_u.

AUDIO LEVEL METERS

Are visual measurement devices divided in different categories following the dynamic behaviour (reaction time and release time) and the measured average level. The meters readings tell about just technical data: average level. quasi-peak, peak.

VU METERS

Introduced by Bell and American Broadcasters, the VU meter (Volume Unit) that look as old as RadioTV transmission, has an even older concept, having a relationship with a model developed for long distance telephone lines.
Used to measure the medium value of the actual signal, rather teh volume (intensity) perceived.
By definition the reading value of Ø match the power of 1 milliwatt (mW) of a 1Khz sinewave on a 600Ω load.

The reading scale is extended from -20 and +3 Volume Units (VU); the 100% value can be set with the used operative level (SOL) but usually is 1.23V on a 600Ω load, corresponding to +4dBm.
Integration time and fall is 300ms, about the lenght of a syllable.
One more version is the NBC-meter; it has the same carhacteristics but the reading scale is extended between -60 and ØVU.
Sometimes there could be a nonconformity of the reading of the same signal between meters, especially when professional and cheap units are used together. The reading sensitivity should be on both fronts of the audio signal cycle. The cheap units are sensible only to a front of the cycle and the reading error is due to the fact that most of the audio signal is asimmetrical.

PEAK PROGRAMME METERS

These instruments read the volume peak of an audio signal. They have a fast attack time and a relativley slow release time to give the user the chance to read the value.
Ther eare two kind of PPM recognised by IEC with three different scales and the Nordic, that is different, even if still recognised.

IEC 268-10 Type I meters, and the Nordic scale variants

It has an integration time of 5ms, necessary to reach 2dB under the reference level.
Fallback time is 20dB/2s.
Voltage reference is 1.55V (+6dBu).
No matter what shape it has (coil, led, plasma and so on) the Type I model can be recognised by the wide externsion of its scale that usually goes from -40dB to+55dB (used in Germany) or from -36dB to +12dB on the Nordic scale.
Both scales are Type I, but the Nordic is marked 9dB higher.

IEC 268-10 Type IIa and IIb meters

Following this specifics are: BBC (Type II) and EBU (Type Iib).
The signal dynamic range is narrower on the Type I.
Integration time is 10mS.
There are few differences compared to the previous one but here the reading is

slighly slower on the isolated transients. The response is a “quasi-peak” meter, used to balance the programmes than a clinical reading.
It has a good reading for speach and music.
The BBC or PPM UK scale shows numbers from 1 to 7, each representing a 4dB variation.
The reference level is 1,94V reached at the “6” value.
The EBU scale has a range from -12 to +12.
The reference level is 2.28V (+9dB) corresponding to +9dB on the scale.

DIN – Pflichtenheft 3/6
The dynamic response of this instrument reach -3dB in 3ms and -2dB in 5ms.
Fallback time is 20dB/1.5s.
The reading range is between -50dB and +5dB.

In America and Australia VU-meters are mainly used. In Europe the EBU recommends to use PPM (Peak Programm Meters) following IEC 268-10 specs for analogue domain and IEC 268-18 for digital domain. This meter cathegory is called QPPM (Quasi Peak Programme Meter) wich reading omit small transients simulating the human ear behaviour.

VU and PPM meters has been originally developed to measure the signal level to cope with audio signal for productions, reproduction and transmission instruments.
The VU meter has a slower ballistic compared to PPM showing a value between the average and the peak of a complex wave.
The VU meter has a flat frequency response so is not a reference for the non linear nature of human ear. This results in a big reading deviation that do not correspnd with the change of the strenght of the perceived volume.
More important is that these devices can lead to mistakes in sugjective reading of the operators.
Even between the most expert operators, the VU meter is quite difficult to interpret due to its dynamic carhacteristic and the reduced dynamic interval.
The usable dynamic range is about 23dB and the upper range of 6dB is dedicated to 50% of the entire signal.
Expert operators usually refer to their listening to balance the different elements of a programme and to set up the general volume, checking the VU or PPM meter to be sure that signal peaks won't overload the equipment.
The PPM meter respond very fast to changes to the signal level. It has been designed to help to detect peaks or transients that would exceed the distorsion of the device. Human ear is not sensitive to instantaneous peaks of a signal level that even if present in a sound program won't affect the perceived volume.
For a stable sinewave, the reading difference between a medium signal (VU) and a peak signal (PPM) is 3dB. For a complex sound programme (speach or music) the difference between medium and peack level can be between 10 and 12dB.
The reading gap between a VU meter and a PPM meter is called *Crest Factor*.

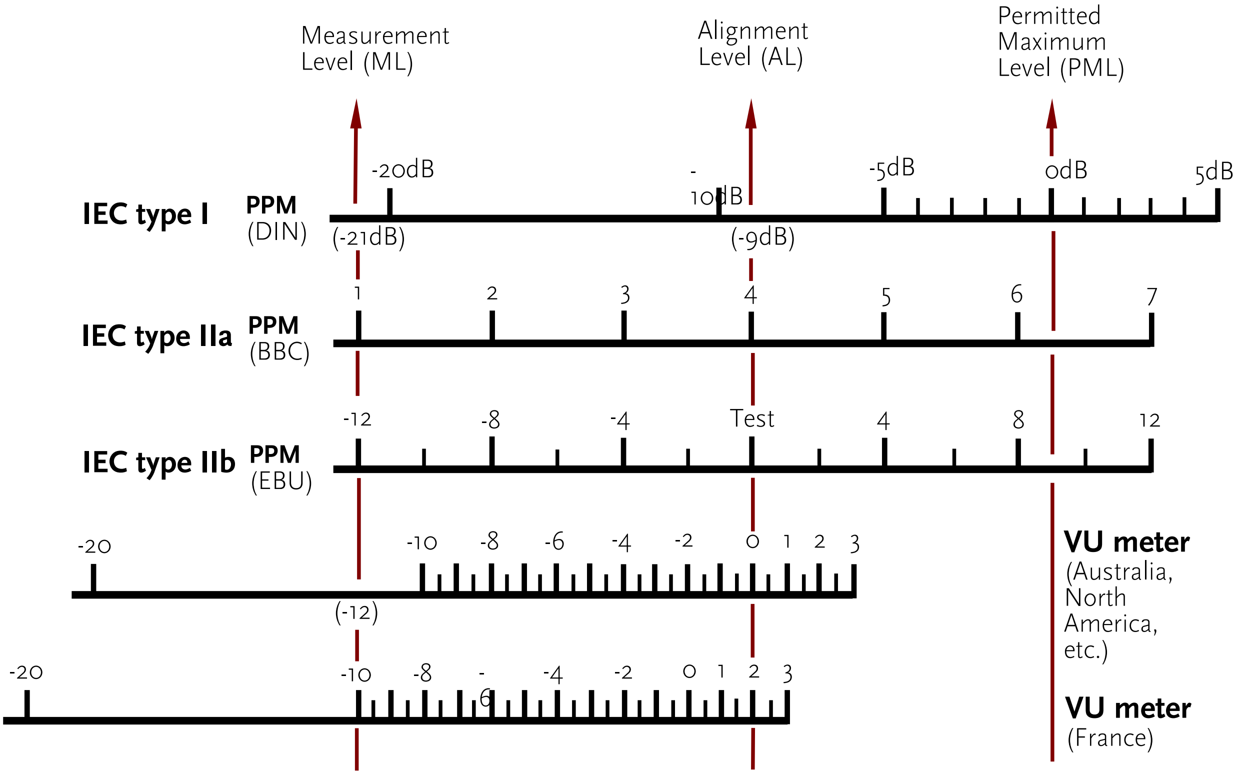
Line up the audio signal means optimise the signal level for the transmission channel. Align and audio circuit consist generally in estabilish analogue levels corresponding to a specific digital lineup.
In an analogue world, due to the circuits imperfections, like for instance the cross-talk phenomenon, there are three kinds of line up levels:

- Alignment Level (AL) Is the one at the beginning of the recordings or left on during absence of signal in the tranmission lines.
  Usually the 1kHz frequency is used, continuous or interrupted, but also 400Hz can be used.
  Il the level of a sinewave 9dB under the PML. This level is set to “Test” or “Ø” on the used Programme Level Meter.

- Permitted Maximum Level (PML) Il the level of a sinewave that equals to the maximum programme signal allowed, which peak signal should exceed this amplitude just in rare events. It corresponds to the peak level on a “Radio link”. Is set to 9dB higher than AL, except few countries like UK where is 8dB to adapt to the used unit scale.

- Measurement Level (ML) Set to 12dB lower than AL. Is a quite low kind of signal, used for technical measurements like for istance the frequency response. If this signal would be higher it could cause “cross-talk” between adiacent circuits or played back too loud on reference loudspeakers.

The relationship between these three signal levels and the most common Program Meters used around the world is shown in the following schemes:



VOLTS	dB_u	IEC I Nordic IEC 268-10 I	IEC IIa BBC IEC 268-10 IIa	IEC IIb EBU IEC 268-10 IIb	DIN(RTW) IEC 268-10 DIN 45406	VU STANDARD	VU N. AMERICA AUSTRALIA	VU FRANCE	EBU R68	SMPTE RP 155	DIN
12.277	24									0dBFS	
10.941	23									- 1	
9.752	22									- 2	
8.691	24									- 3	
7.746	20									- 4	
6.904	19									- 5	
6.153	18								0dBFS	- 6	
5.484	17								- 1	- 7	
4.887	16								- 2	- 8	
4.356	15								- 3	- 9	0dBFS
3.882	14		8						- 4	- 10	- 1
3.460	13								- 5	- 11	- 2
3.084	12	+ 12	7	+ 12					- 6	- 12	- 3
2.748	11	+ 11		+ 11	+ 5				- 7	- 13	- 4
2.449	10	+ 10		+ 10	+ 4				- 8	- 14	- 5
2.183	9	+ 9		+ 9	+ 3				- 9	- 15	- 6
1.946	8	+ 8	6	+ 8	+ 2				- 10	- 16	- 7
1.734	7	+ 7		+ 7	+ 1	+ 3			- 11	- 17	- 8
1.546	6	+ 6		+ 6	0	+ 2			- 12	- 18	- 9
1.377	5	+ 5		+ 5	- 1	+ 1			- 13	- 19	- 10
1.228	4	+ 4	5	+ 4	- 2	0			- 14	- 20	- 11
1.094	3	+ 3		+ 3	- 3	- 1	+ 3		- 15	- 21	- 12
0.975	2	+ 2		+ 2	- 4	- 2	+ 2		- 16	- 22	- 13
0.869	1	+ 1		+ 1	- 5	- 3	+ 1	+ 3	- 17	- 23	- 14
0.775	0	test	4	test	- 6	- 4	0	+ 2	- 18	- 24	- 15
0.690	- 1	- 1		- 1	- 7	- 5	- 1	+ 1	- 19	- 25	- 16
0.615	- 2	- 2		- 2	- 8	- 6	- 2	0	- 20	- 26	- 17
0.548	- 3	- 3		- 3	test	- 7	- 3	- 1	- 21	- 27	- 18
0.489	- 4	- 4	3	- 4	- 10	- 8	- 4	- 2	- 22	- 28	- 19
0.436	- 5	- 5		- 5	- 11	- 9	- 5	- 3	- 23	- 29	- 20
0.388	- 6	- 6		- 6	- 12	- 10	- 6	- 4	- 24	- 30	- 21
0.346	- 7	- 7		- 7	- 13	- 11	- 7	- 5	- 25	- 31	- 22
0.308	- 8	- 8	2	- 8	- 14	- 12	- 8	- 6	- 26	- 32	- 23
0.275	- 9	- 9		- 9	- 15	- 13	- 9	- 7	- 27	- 33	- 24
0.245	- 10	- 10		- 10	- 16	- 14	- 10	- 8	- 28	- 34	- 25
0.218	- 11	- 11		- 11	- 17	- 15	- 11	- 9	- 29	- 35	- 26
0.195	- 12	- 12	1	- 12	- 18	- 16	- 12	- 10	- 30	- 36	- 27
0.173	- 13	- 13			- 19	- 17	- 13	- 11	- 31	- 37	- 28
0.155	- 14	- 14			- 20	- 18	- 14	- 12	- 32	- 38	- 29
0.138	- 15	- 15			- 21	- 19	- 15	- 13	- 33	- 39	- 30
0.123	- 16	- 16			- 22	- 20	- 16	- 14	- 34	- 40	- 31
0.109	- 17	- 17			- 23		- 17	- 15	- 35	- 41	- 32
97.5m	- 18	- 18	0		- 24		- 18	- 16	- 36	- 42	- 33
86.9m	- 19	- 19			- 25		- 19	- 17	- 37	- 43	- 34
77.5m	- 20	- 20			- 26		- 20	- 18	- 38	- 44	- 35
69.0m	- 21	- 21			- 27			- 19	- 39	- 45	- 36
61.5m	- 22	- 22			- 28			- 20	- 40	- 46	- 37
54.8m	- 23	- 23			- 29				- 41	- 47	- 38
48.9m	- 24	- 24			- 30				- 42	- 48	- 39

TABLE OF SIMILARITY BETWEEN VOLTAGE AND METER VALUES

From the table we can note that intruments following the EBU R68 have an alignment tone at $-18dB_{FS}$
decribing a value of ØdB$_U$ in the analogue domain.
On the other hand, intruments following the standard SMPTE RP155 have an aligning tone of decribing a value of $-20dB_{FS}$ in the analogue domain.
This drive to continuous confusions in setting up devices and exchanging material from different countries.

DIGITAL METERS

With the advent of digital domain, we now need to define two more specifics:

- Maximum Coding Level Is the level of a sinewave which peack correspond to the maximum coding value in the used digital system.

- Full Scale (FS) The maximum value of digits available in a digital system. A sinewave at its maximum value correspond to ØdB_{FS}.

In the digital domain, the requested analogue level for ØdB_{FS} can vary from coutry to country.
The EBU R68 specific has been used in most of European countries. This standard defines +18dB_u at ØdB_{FS} while US facilities use SMPTE RP155 which value is +20dB_u at ØdB_{FS}.
In France, Japan nad other countries the level is +22dB_u at ØdB_{FS}.

K-system
Introduced by Bob Katz, an America mastering engineer, these are three different type of scales:
K-20 has 20dB of headroom over ØdB.
K-14 has 14 dB of headroom over ØdB.
K-12 has 12 db of headroom over ØdB.

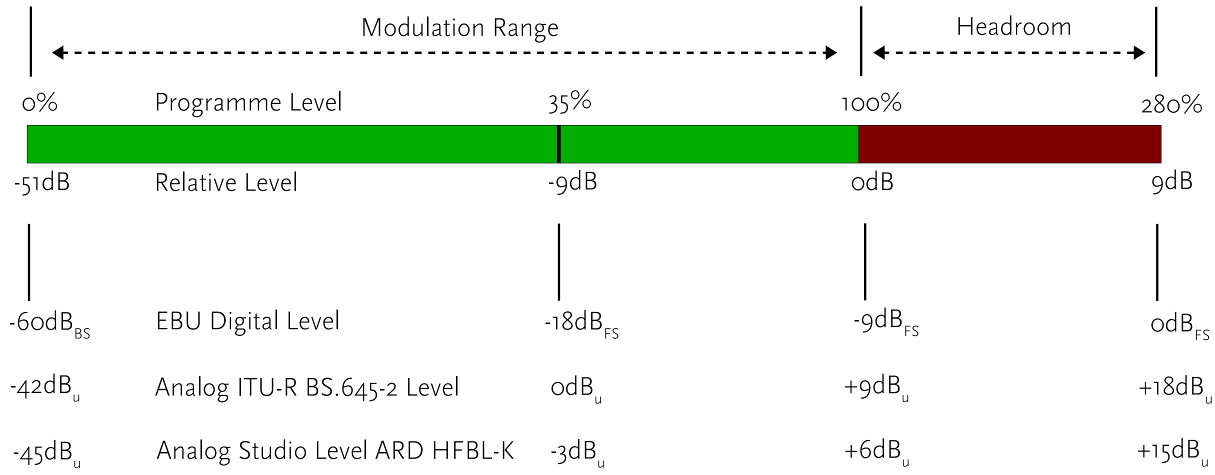
On those scales the green colour is usd under Ø, the yellow is beteen Ø and +4dB and the red is used over +4dB.
Every scale can be used with three different time/frequency relationship:
RMS Used with a frequency response between 20Hz and 20KHz ±0.1dB
Leq(a) Uses A A-weighting (IEC A) and an Integration Time of 3s.
Zwicker Uses the volume Zwicker model.

To calibrate the listening, is used pink noise at ØdB level, corrsponding to 83dB(C) at th elistening position.

Dorrough
Produced by Dorrough, the scale shows the volume relatively to the peak modulation.
The range is between -36 to +3dBm.

ITU-R BS.1771, Type I e Type II
The Internationa Telecommunication Union defined the cahrachteristics for a meter able to measure the volume with the option for digital peaks.
It has introduced a new unit of measurement: LU (Loudness Unit).
Is related with the dB scale in a way that a gain loss of 10dB results in a reduction of 10 value on a LU scale.
Type I Electronic display with resolution of one or more segments per Loudness unit.
TypeII Electronic display with resolution of a segment per 3 Loudness units.

comparison between QPPM



Considering the scale settings, the “full scale” (100%; ØdB) like the specified “Headroom” should match the “Attack Time” and “Release Time” of the relative Programme Meter.
For instance the VU-Meter that can be considered relatively slow, obviously need an appropriate Headroom due to the invisible signal peak.
Consequently the difference between 100% and the aligning level need to be smaller than other considered.
The ITU-R BS.645-2 specifics define that for the VU Meter the signal 100% has to be tha same as the aligning level, while for QPPM il 100% has to be 9dB higher.

reading the Programme Meters

When monitored with a PPM, the peak of the sound programme will read a value between 6 and 9 dB over the alignment level.
The difference depends by the time constant of the meter, the lenght of the peak and the kind of sound programme.
When monitored on a VU meter the level of the programme will be read about 2dB under the aligning level. This will depends by the kind of sound programme.

headroom

The headroom is the reading value of the used meter that we use to protect from the invisible peaks due to the response slowliness.
That's why the VU-meter need more Headroom ($-18dB_{FS}$) compared to the QPPM ($-9dB_{FS}$).
The Sample Peak Programme Meter theoretically do not need headroom, having such a reading speed to read the value sample by sample.
Is a security level that we use to avoid oveloads.

TABLE OF USED PROGRAMME METERS

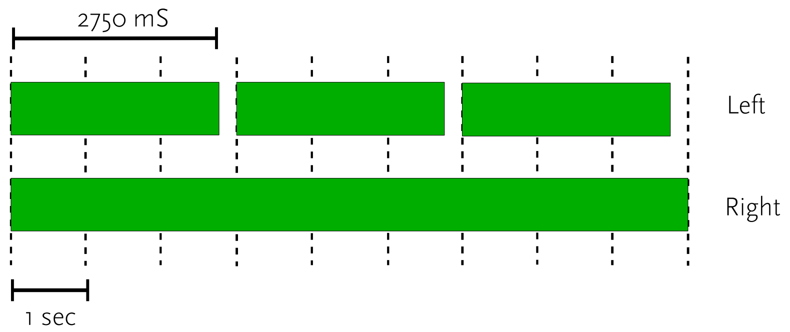
Programme Meter	Specifics	AL (35%)	PML (100%)	Clipping Level	Scale	Invisible Peak	Attack Time (Integration)	Release Time (Decay)
Vu Meter	ANSI C 16.5 IEC 268-17	0 VU (0dBu)	0 VU		-20 ÷ +3 [dB]	+13 ... +16 dB	300ms/90%	300ms / 10%
DIN (QPPM)	DIN 45406 IEC 268-10 ARDPfl.H.A RDPfl.H.3/6	9dBr (0dBu)	0dBr (+9dBu)	+16dBr +25 dB_u	-50 ÷ +5 [dB]	+3 ... +4 dB	10ms / 90% 5ms / 80%	20dB / 1.5s (13dB/s)
BBC (QPPM)	IEC 268-10	4 (0dBu)	6 (+8dBu)	(+24)	1 ÷ 7	+4 ... +6 dB	10ms / 80% 20ms / 90%	24dB /2.8s (8.6 dB/s)
EBU (QPPM)	EBU 3205-E IEC 268-10	0dB (0dBu)	+9dB (+9dBu)		-12 ÷ 12 [dB]	+4 ... +6 dB	10ms / 80%	24dB /2.8s (8.6 dB/s)
EBU Digital (QPPM)	EBU IEC 268-18	-18dB_{FS} (0dBu)	-9dB_{FS}	0dB_{FS}	-40 ÷ 0 [dB]	+3 ... +4 dB	5 ms / 80%	20dB / 1.7s (12 dB/s)
DIGI PPM IRT Proposal	IRT IEC 268-18	-9dBr (35%)	0dBr (100%)	≤+10 dBr	-50 ÷ 10 [dB]	+3 ... +4 dB	5 ms / 80%	20dB / 1.7s (12 dB/s)

ALIGNING TONES

The tone used for the Audio Aligning, has also the duty to identify the used channels of the system.

STEREO

In a stereo sistem, the left channel, or channel 1 is identified by a 1Kz tone at aligning tone, interrupted for 250mS every 3S like to following diagram.



The interruption make possible to hear the phase realtions and to identify the mono mix.

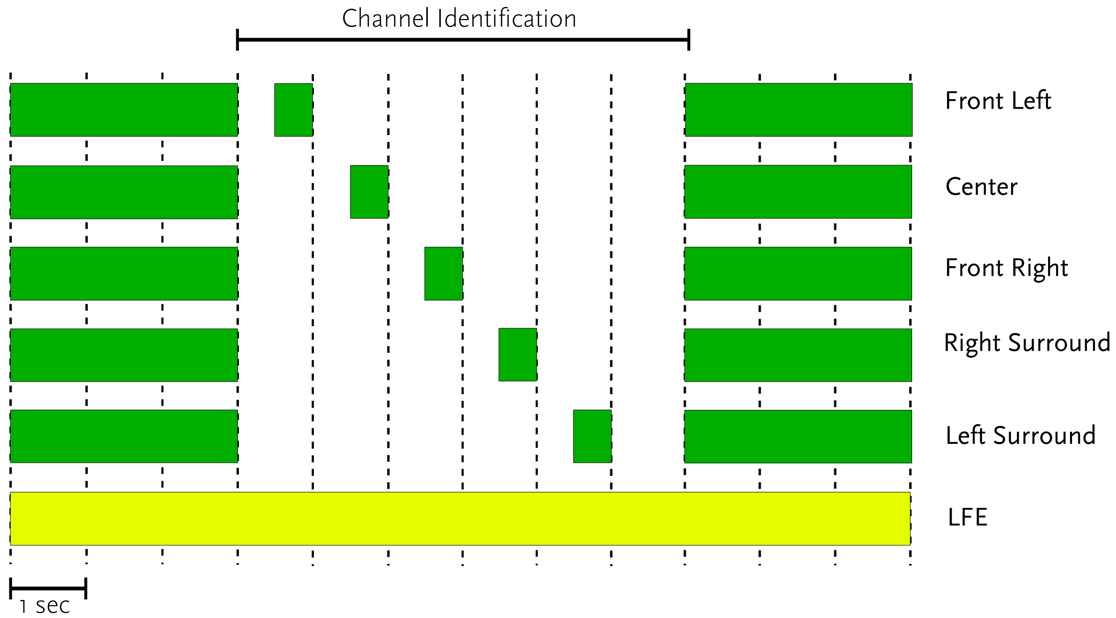
When different languages are broadcasted on different channels, the principal one is distinguished by the 1KHz, while the secondary one has a 400Hz tone.

For this channel configuration EBU advice an allocation of the audio signals according to the table

	Mode					
	Mono One Programme	**Stereo** One Programme	**2 Channels** Two separate programmes	Mono programme with reverse talkback	Stereo programme in MS stereo	Commentary and international sound
Channel 1	Complete mix Mono	Complete mix Left	Channel A	Complete monomix	Mono signal M	Commentary
Channel 2	Complete mix Mono	Complete mix RIght	Channel B	Reverse talk-back	Mono signal S	International sound

MULTICHANNEL

For a multichannel configuration, the aligning signal is carried out sending the 1KHz tone on every channel for 3S followed by 0.5S of silence. After wich all the channels are identified clockwise from the front left.
The identification is a pulse of 0.5S followed bu an empty interval of 0.5S to then move to the following channel.
After the complete identification cycle there is an empty interval of 1S and the whoe cycle starts again.
The LFE channel carries a continuous 80Hz tone. Even though the tone is recorded at Aligning Level, this channel will play back 10dB over the main channels.



The channel identification will adapt to the kind of used surround, from which total lenght we understand how many channels we are using:5.0; 6.0; 5.1; 7.0; 7.1 and so on.
For this channels configuration, EBU advice to allocate the channels following the table:

1	2	3	4	5	6	7	8
L	R	C	LFE if available	LS MoS (-3dB)	RS MoS (-3dB)	A if available	B if available

Where:

Symbol	**Audio Signal**
L	Left
R	Right
C	Centre
LFE	Low frequency effects
LS	Left surround
RS	Right surround
MoS	Monophonic surround
A	Left (two channel stereo)
B	Right (two channel stereo)

LEVEL METER TECHNICAL SPECIFICS

PEAK TO PEAK VALUE (VPP)

Is the maximum deviation in absolute value (positive and negative). This value is measured between the “zero” line and the maximum reached in each area.

ROOT MEAN SQUARE RMS

Is described by the mathematical expression used to calculate it from the signal peak and relate a continuous signal (DC) with an alternate one (AC).
This value is calculated differently for different waveform.
For a sinusoid waveform the rms value is 0.707 of the peak value, with the formula:

$$\frac{Vp}{\sqrt{2}}$$

For a square wave the RMS valu is the same as the peak value.

INTEGRATION TIME

Is the time needed by the instrument to reach the right reading value, fome the moment that a continuous signal is applied to the circuit.
Is described in mS.

FALL TIME

Is the time needed by the instrument to come back to the rest position once the continuous signal is removed to the circuit.
Is described in *n*dB/*n*mS.

CREST FACTOR

The difference between the reading of the average value of a VU meter and the peak value of a PPM, calculated from the peak amplitude of the waveform divided by the RMS value of the waveform:

$$C = \frac{|X|\,peak}{Xrms}$$

Is a dimentionless quantity usually described by a positive rational number. In commercial products it is also commonly stated as the ratio of two whole numbers, e.g. 2:1

LEQ

Loudness EQuivalence. Is the average value of sound level measured in time.
The signal can be an audio file and/or a live event.
Is obtained calculating the RMS value in dB referred to a level prearranged or defined.
This measurement is always associated to filters with specific “weighted” curves.

- Leq(Linear) no weight in the frequency spectrum.
- Leq(A) The A weight is used at the sound source. Is an approximation of the 40 phon curve of the di Fletcher-Munson graphic.

- Leq(B) B weighted. Is modified compared to the previous one for a listening to a lower sound pressurres. The low frequencies are enphasized.
- Leq(C) C weighted of the frequency spectrum. Is modified for even lower sound pressures with the low frequencies even more enphasized.
- Leq(D) D weighted. Used to measure of aircrafts noise.
- Leq(M) Introduced by Dolby Laboratories Inc. M means "Movie"
- Leq(RLB) Revised Low frequency B-weighting. Is a high pass filter with a 50hz roll off.

LeqA ed Leq()

Measuremnt methods for an subjective listening, introduced to regulate the sound level perceived by the audience in films and TV.
Developped by Dolby Laboratories to measure the average sound level perceived along the whole lenght of a audio programme, calculaing the "nuisance" reaching the listener.
The factors considered are: the esposition time of the sound programme and the frequency response of the human ear.
The measurement is based only on electrical data assuming a calibration of the listening environment.
The difference between the two methods is the used reference level. In Leq(m) method is used the reference level for cinema playback, while in the Leq(A) the level of a conversation.
The sound of each track is weighted in frequency and filtered according to the CCIR 468 regulations (the reference is ØdB at 2KHz). Every signal are captured and summed on a single reading value. The average value is captured on the whole film lenght.
During the measurement the so called "annoyance factor" is calculated.
The weighting of the m filter is a flat response for the frequencies between 30Hz and 16KHz.

dialnorm

This measurement was born for mixing films and the term means "Dialogue Normalisation". It measure the level of the sonic volume of dialogues referred to a value of $-31dB_{FS}$ in surround applications.
The whole sonic volume perceived by the listener should be determined and kept constant using the dialogue level with a prearranged relationship with the music and sound effects without loosing ntelligibility.
This value is determined using techniques already used in noise pollution measuments, but the electric signals are referred to the value $Ø dB_{FS}$ instead of 20μPa pressure level.
This technique measure the equivalent energy A-weighted Leq(A) as defined by IEC60804 specifics.
The reference value of $-31dB_{FS}$ is used as threshold value.
Decoding values over -31dBFS brings a reduction of the overall audio signal level of (31dB + Dialnorm)dB.
The dynamic of the sound programme won't be alterated, the global leve is controlled in relationship with the reference value without being noticed by the listener.
The ATSC A/52 specifics define the broadcast of the Dialnorm parameter as part of the metadata.

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SPECIFICATIONS

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EBU Tech 3276 s1
EBU Tech. 3282–E - Digital audio alignment levels Handbook for the EBU R–DAT Levels tape
EBU Tech 3304 - Multichannel Audio Line-up Tone
EBU Technical Recommendation R38-1998 - Allocation of audio channels in analogue tape recording formats for international exchange of programmes
EBU Technical Recommendation R49-1999 - Tape alignment leader for the exchange of television programmes
EBU Technical Recommendation R68-2000 - Alignment level in digital audio production equipment and in digital audio recorders
EBU Technical Recommendation R72-1999 - Allocation of the audio modes in the digital audio interface (EBU document Tech. 3250)
EBU Technical Recommendation R73-1999 - Alignment of record flux levels on the longitudinal audio tracks of Betacam SP recordings, to facilitate programme exchange
EBU Technical Recommendation R89-1997 - Exchange of sound programmes on Recordable Compact Discs, CD-R
EBU Technical Recommendation R91-2004 - Track allocations and recording levels for the exchange of multichannel audio signals
EBU Recommendation R117-2006 - The use of high level digital audio material in the production chain

IEC 268-10
IEC 268-18
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ITU-R BS1771

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rev. August 2008