NOISE ON A VIDEO SIGNAL

INTRODUCTION

This handout will define noise, and discuss the sources of noise which are likely to affect the video signal.

The visual affect of noise on television pictures is highly subjective. The use of the E.B.U. rating scale, which the observer uses to classify his reaction to the noise, is described.

The methods of noise measurement will be described. These form a series of standardised tests, whose results can be interpreted by BBC, P.O. and other engineers working with the BBC on signals and/or systems, (eg. during acceptance of plant).

1. NOISE

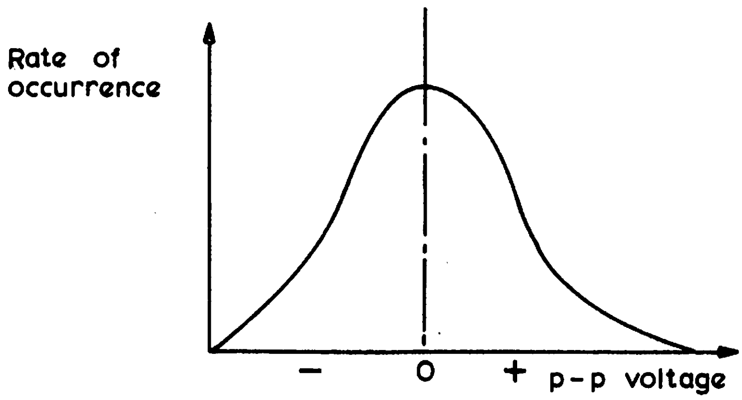
Noise can be defined as any <u>unwanted</u> signal which appears at the output of a system. It can be divided into two categories.

1.1 Coherent Noise

A repetitive, interfering signal (whose relationship with time is observable) can be called coherent noise. For example, hum and its harmonics, or carrier breakthrough from a transmitter.

1.2 Random Noise

Random noise is an unpredictable, time-varying signal. Its energy is contained in pulses, which range from infinite height---zero duration pulses, to zero height---infinite duration pulses. The order in which this range of pulses is produced is random, but there is a gaussian relationship governing the peak to peak height of a pulse and its chance of occurring. At a given noise energy:-



Its usual cause is the random motion of thermally excited charge-carriers in conductive material.

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2. NOISE SOURCES

The programme chain, from origination to viewer, may be considered to fall into three parts:-

a) Programme origination equipment (cameras, T.K., V.T.R. etc)
N.B. noise occurs in active picture period only, since blanking is applied near to the channel output.

b) Distribution path from studio to transmitter (cables, amps, equalisers, radio links.) N.B. noise added to blanking periods as well as active picture time.

c) Transmitted path from transmitter to receiver
N.B. noise added to blanking and active picture.

Below is a table showing some of the likely noise sources, and where the noise may be introduced.

NOISE MECHANISM	NOISE SOURCE	Orig 1	Dist 2	Tx/Rx 3	COMMENT
Thermal excitation of charge carriers	Resistors in low level stages, etc	✓	✓	✓	Random (flat spectrum)
As above, occurring in between mod and demod of an fm system, or on signal to be equalised.			✓		Random (non flat spectrum)
shot noise & flicker noise	Active devices handling low signal levels	✓	✓	✓	Random (")
hum and its harmonics	Circulating earth currents. P.S.U. faults		✓		
Inverter noise	P.O. repeaters using dc phantom power + inverters		✓		Usually 3 kHz
R.F.I.	Local MW transmitter.	✓			
	In band heterodynes at the o/p of a mod-demod process due to spurious signal.		✓		
Impulsive Interference	Car ignition		✓	✓	
	SCR switching transient	✓	✓	✓	

3. SUBJECTIVE EFFECT

The effect of noise on television pictures is to cause an impairment in the quality of the viewed picture.

3.1 Subjective rating scale

As a guide to the seriousness of an impairment, engineers can communicate using a subjective rating scale. The BBC uses the five-point impairment scale, This replaced the EBU 6-point scale (where Grade 1 = imperceptible; & Grade 6 = unusable) in October 1978.

Grade 5	Imperceptible	Excellent
Grade 4	Perceptible but not annoying	Good
Grade 3	Slightly annoying	Fair
Grade 2	Annoying	Poor
Grade 1	Very annoying	Bad
Describes	IMPAIRMENT	QUALITY

However, the accuracy of this assessment will depend upon

viewing conditions	Ambient light, monitor brightness and contrast distance from observer, etc.
the observer	Technical or non-technical background, experience, state of health.
programme material	Noise which would give grade 3 on test card would be 4 or 5 on 'Tom and Jerry'.

Other distortions, eg linear distortions such as reflections or poor l.f. response, may be present, in which case, the impairment rating represents the subjective effect of all distortions. This will prevent an accurate assessment being made of just the noise present.

3.2 Noise measurement and subjective effect

If we could measure noise on a meter, (calibrated in grades?) such that, no matter what kind of noise was present, the reading always gave the subjective effect, we would have a perfect noise measuring system.

In practice, this is difficult to achieve, but we can approach it when random noise is the major component.

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3.2.1 Coherent noise and its subjective effect

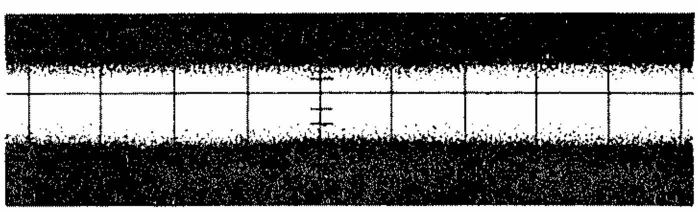
The subjective effect of coherent noise depends on its wave shape. For example, equal peak to peak amplitudes of 50Hz sine wave and 100Hz ripple waveforms do not give the same impairment to a video display.

We cannot therefore produce a measurement instrument to give the subjective effect of coherent noise. It is accepted practice to measure its peak to peak value on an oscilloscope and describe its waveshape.

3.2.2 Random noise and its subjective effect

The subjective effect of random noise depends on its distribution of energy with frequency. The noise impulses appear as a randomly moving "grain" pattern on the screen. If the grain is coarse, (i.e. energy concentrated at low frequencies, say below 1MHz) it is more objectionable than the same energy concentrated in the higher video frequencies, where it produces a finer grain pattern.

It is difficult to measure random noise consistently on an oscilloscope. The highest peak to peak pulses will be most rare in occurrence, and narrow in width, The oscilloscope trace will be a fuzzy line of apparent amplitude around the average voltage, with high value spikes trailing off in brightness above and below the trace.



Since ambient light, trace brightness, and repetition rate cannot be the same for all observers, (in different BBC locations) the peak to peak value seen will differ between observers.

However, the R.M.S. power of the noise can be measured accurately with a true power meter, eg a thermocouple meter. Usually these are too expensive and delicate for use in the field, so a mean-reading meter is used, calibrated against the true power meter.

In tests with a statistically large number of observations under ideal conditions, the peak to peak value of noise seen on an oscilloscope is related to the R.M.S. value of equivalent voltage by a ratio

$V_{p-p} = V_{rms}$ x between 6 and 8 (16 to 18 dB)

$(V_{rms} = \sqrt{Power_{rms} \times \Omega})$

3.3 Summary of noise affecting picture quality

The division of noise into 'coherent noise' sources and 'random noise' sources also divides the video spectrum. Most coherent noise effects occur below 10kHz, and there is no reliable way of relating their amplitudes to the effect seen on picture.

Random noise sources are of infinite bandwidth, which is only limited by the receiver bandwidth and display resolution, (equivalent to approximately 5MHz). The energy lost if measurement does not include those components below 10kHz is minimal.

Therefore it is usual to split the frequency spectrum at 10kHz, that part above being mainly random noise, and below the limit being mainly coherent noise whose subjective effect is not related to an objective measurement.

4. NOISE MEASUREMENT

The principles of video noise measurements are the same as for audio practice.

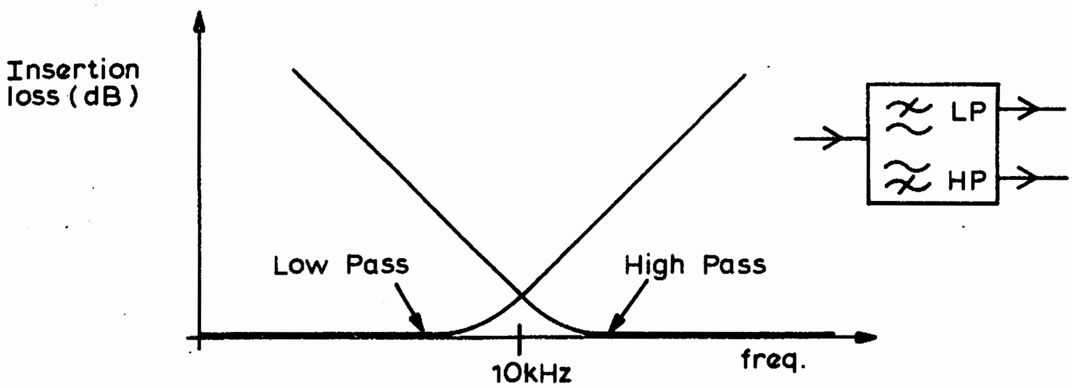
a) establish normal signal level on the line/equipment, usually 0.7 volt at receiving end into a termination. (Picture signal only).

b) terminate input.

c) increase sensitivity of the measuring equipment by a calibrated amount to bring the noise up to a calibration mark.

4.1 Junction filter

The signal can be split at 10kHz by a high pass, low pass network, (ie two outputs) whose insertion loss to each output is shown below.



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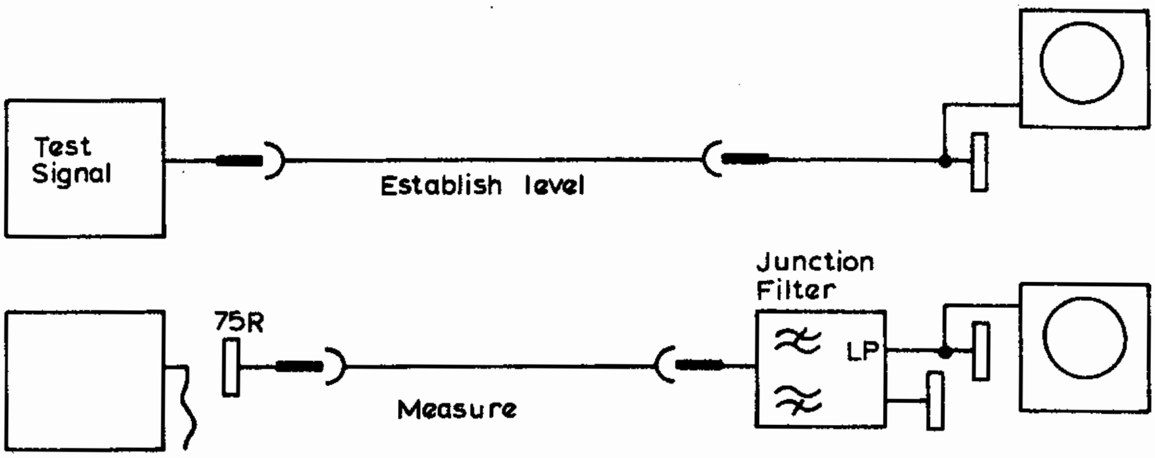
4.2 Measurements below 10kHz   or L.F.N.

Sometimes referred to as below line frequency noise (true for 405, not quite true for 625).



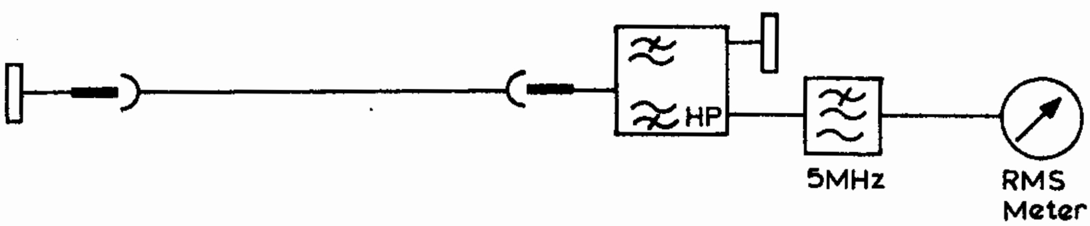
First the measuring equipment is calibrated with normal signal level, i.e. usually Bk to W = 0.7 volt (ignore syncs), so that this occupies say, 5 divisions on the oscilloscope. Then the line input is terminated, and the junction filter connected between line and oscilloscope. Now the oscilloscope is displaying the below 10kHz components of the noise on the line, and its sensitivity is increased until the noise occupies 5 divisions.

$$\text{Signal/noise}_{\text{below 10 kHz}} = \text{change in sensitivity of oscilloscope, in dB}$$

$$= 20 \log_{10} \frac{\text{Picture signal, volts p-p}}{\text{noise amplitude, volts p-p}} \text{ dB}$$

4.3 Total luminance noise (above 10kHz)

This will be mainly random noise. The initial conditions are as in section 4.2. The line input is then terminated and the noise above 10kHz, from the high pass output of the junction filter, is measured on an R.M.S. meter.



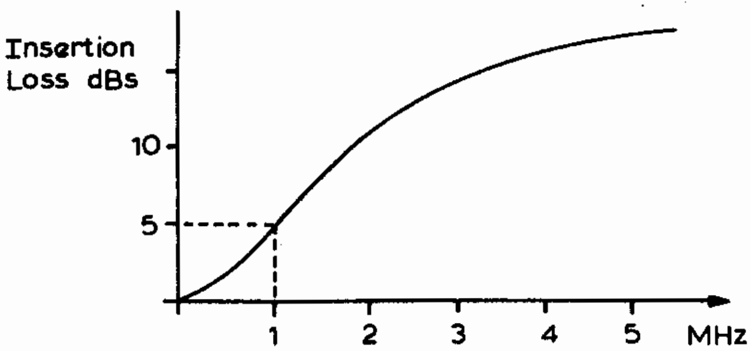
Notice that a 5MHz low pass filter is included to prevent the meter from reading noise which the viewer will not see, i.e. out of band noise. 5MHz is chosen because some European standards have 5MHz as

their upper limits for 625 line transmission. In practice the difference measured using 5.5MHz bandwidth is insignificant.
The signal/noise ratio for luminance total noise is expressed

$$\text{signal/noise} = 20 \log_{10} \frac{\text{Picture signal, volts p-p}}{\text{noise amplitude, volts rms}}$$

4.4 Luminance weighted noise

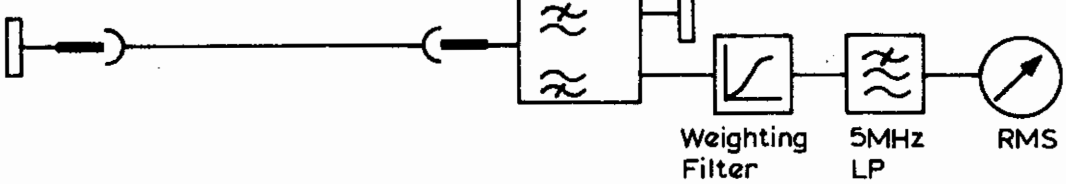
The luminance weighted noise measurement includes a weighting filter, whose insertion loss with frequency is as shown below.



Noise that would cause a coarse 'grain' pattern (more objectionable on pictures is passed straight to the rms meter, but noise that would cause a fine 'grain' pattern (less objectionable) is attenuated.

This means that more noise energy will be needed if the noise is predominantly in the higher part of the video spectrum, to give the same meter reading as a given energy of noise whose energy is predominantly in the lower part of the spectrum.

The resultant luminance weighted signal to noise ratio therefore gives a reading which is proportional to the subjective effect, independent of the energy distribution of the noise with frequency.

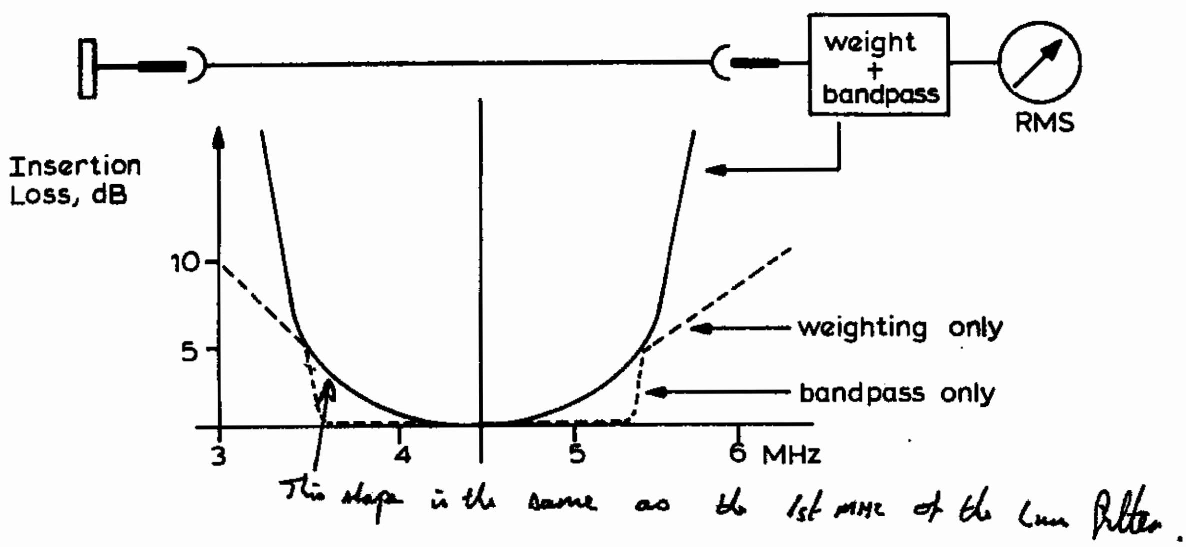


measurement of luminance weighted noise

$$\text{The signal/noise}_{\text{luminance}} \text{ weighted} = 20 \log_{10} \frac{\text{Picture signal, volts p-p}}{\text{noise ampli. weighted, rms}}$$

4.5 Chrominance weighted noise

Any noise introduced after the coder, in the region of 4.43MHz ± 1MHz is decoded down to lower frequency, (0–1MHz), colour noise in the decoder. The previous luminance weighted measurement did not take account of the effect of this on pictures. The effect is that noise at the upper end of the luminance bandwidth, producing fine grain noise in monochrome systems, gives rise to coarse grain colour noise. As the frequency of the noise energy moves away from 4.43MHz the decoded grain pattern becomes finer, consequently appearing less objectionable. The signal is filtered to remove all energy outside 4.43 ± 1MHz (band pass) and the remaining band is symmetrically weighted about 4.43. The initial conditions for measurement are as in section 4.2, and the line then terminated. The noise is passed to the rms meter via the band-pass and weighting filters.



Care must be taken to ensure that 5 MHz low pass is not left in circuit for this test.

4.6 Summary of noise measurements

The first two measurements are made to indicate the degree of noise below (4.2) and above (4.3) line frequency.

The second two give a reading proportional to the subjective impairment of the (mainly random) noise above line frequency on luminance channel (4.4) and chrominance channel (4.5) signals.

The junction, weighting and band-limiting filters are contained within a measuring set, eg. ME1/503, along with the necessary amplifiers, attenuators and the rms meter.

5. NOISE MEASUREMENTS IN THE PRESENCE OF SYNCS AND/OR BLANKING

There are two cases where it is desirable to measure noise in the presence of syncs and/or blanking.

a) to measure the signal/noise of equipment that cannot operate normally without generating syncs or blanking.
eg. VTR's, cameras, T.K.'s, caption scanners.

The measurement may be required during acceptance tests of equipment from a manufacturer or S.C.P.D., or when some part of the signal chain which handles low-level signals becomes suspect, eg., head amps, photomultiplier cells, camera tubes.

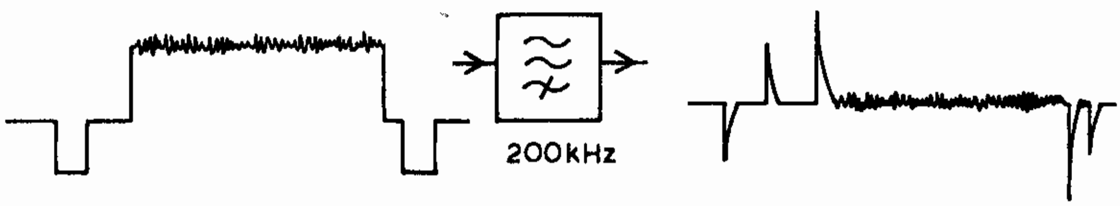
b) to measure the signal/noise of the distribution chain under normal working conditions during programme hours.
Lines occurring in field blanking are blanked at source, so that the noise super-imposed on a line in field blanking must have been added during distribution of the signal to its various destinations. Line 12 (and 325) is allocated for noise measurement, and is not re-inserted or blanked at any intermediate station in the distribution network.

5.1 Gated noise meters

The gated noise meter can only be expected to measure noise in the band above line frequency, since components of syncs are occupying the spectrum around line frequency and below.

Thus it will be used to measure random noise. Usually the sync components are removed by a 200kHz (typically) high-pass filter, which removes any pedestal on which the noise is superimposed as well as the syncs. (Necessary in line 12 measurement where the changing mean level of the picture signal might affect the result).

A typical input waveform in the case of a camera would be noise on a mid-grey pedestal to avoid black or white clippers in the camera video chain. (i.e. 'lift' added to the noise).



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After passing through the 200kHz high pass filter, the signal contains spikes due to differential sync and blanking edges together with noise waveform. The mean level of this waveform is the same as the noise alone.

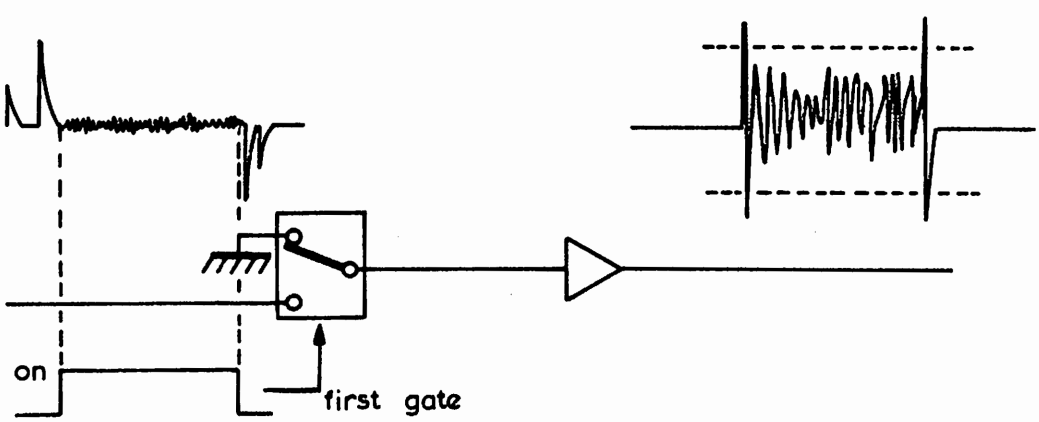
To avoid measuring the spikes, the signal is passed through a gate which is only opened inside active line time.

Meters used for line 12 and 325 noise measurement are designed to sample on one line per field only. For use on cameras, etc., they measure on one line during active picture time, (eg 29 and 342).

Older type meters may be found which summed the result of sampling every line of active picture period, (less sensitivity needed). Thus they could not be used on the distribution chain in normal programme hours.

5.2 ME1/508 A Typical Gated Noise Meter

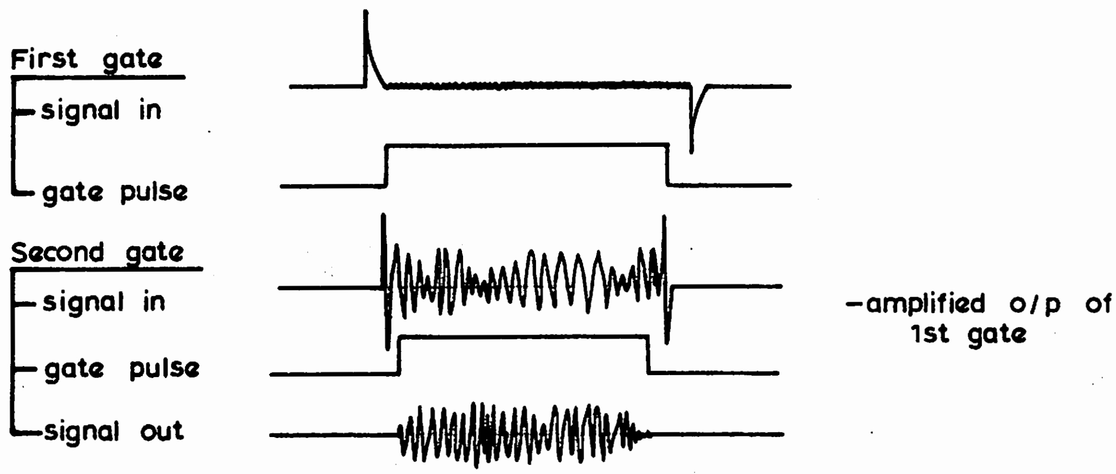
This uses a double gating principle in the following way. The signal passes through the 200kHz h.p. filter and then to the first gate.



The gate is only open during active line time, gating through as much of the noise as possible without including the blanking spikes.

This process inevitably generates small switching spikes, which are likely to be larger than the smallest noise we wish to measure. The solution is to amplify the noise and switching spikes, probably clipping the spikes in the amplifier, and pass to a second gate. The second gate is opened inside the window of the first gate, removing the spikes due to the first gate. The signal level at the second gate is high, and its spikes are small compared to the signal.

The waveforms of the signal and gate pulse at the two gates are shown below:-



The output of the second gate is rectified and used to charge a capacitor which holds the charge for one field. It is discharged just before the next sample is taken. The voltage across the capacitor is buffered to drive a meter.

The meter must be calibrated against a true rms meter from time to time, as its action is quasi-peak reading.

No mention has been made until now of the 5MHz low pass, or the luminance and chrominance weighting filters which are used to give readings of:-

Luminance total noise	as in 4.3
Luminance weighted noise	as in 4.4
Chrominance weighted noise	as in 4.5

These are switched into circuit before the detector as required to give the correct frequency shaping to the noise. To make up for the noise not measured between 10kHz and 200kHz, a small boost is given to the response around 200kHz.

This meter should give the same reading on continuous noise, i.e. a terminated circuit, as the methods outlined in section 4, if provided with a feed of external syncs to trigger the gating circuits.

5.3 Summary - gated noise meters

A gated noise meter samples the noise during active line time and gives a reading of signal to noise ratio in the presence of syncs and/or blanking. It may be used on a line in field blanking to measure the noise added in the distribution chain, or used with a

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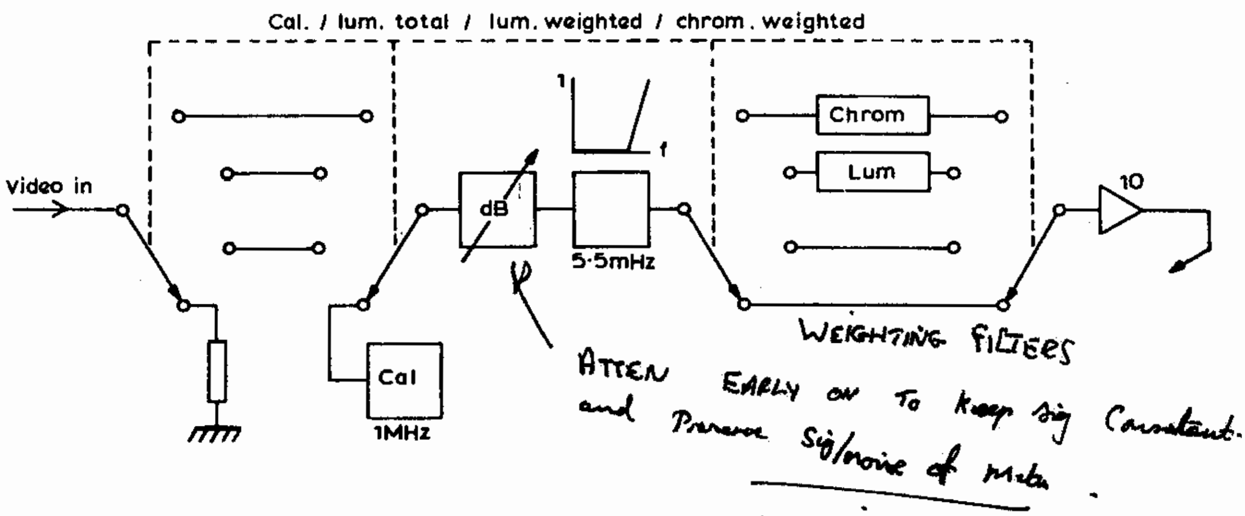
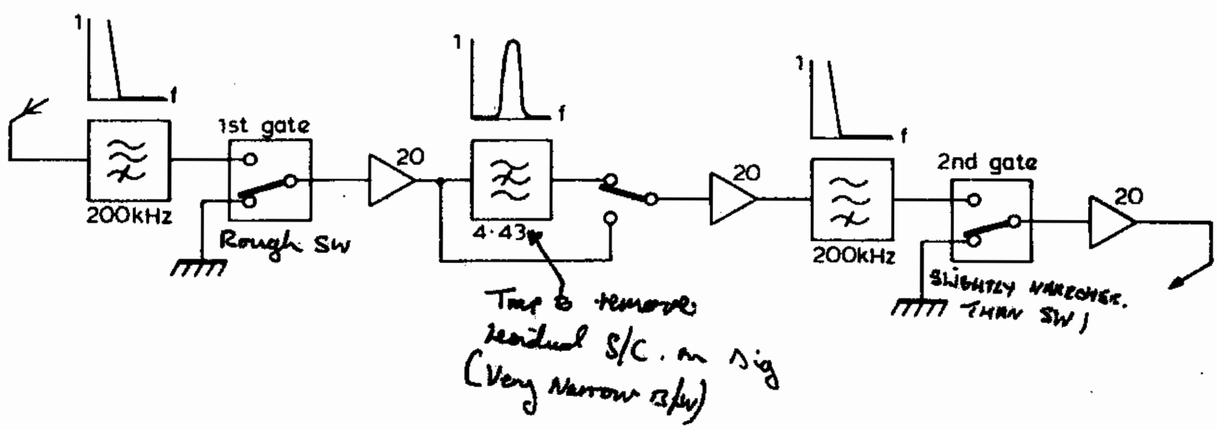
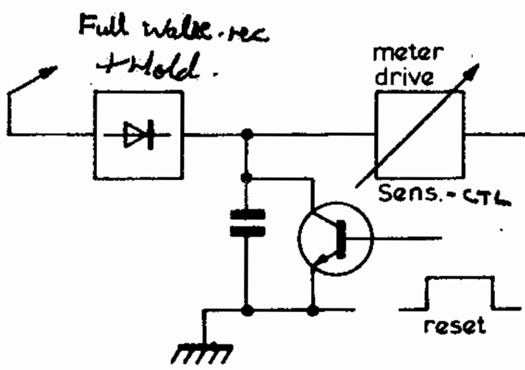
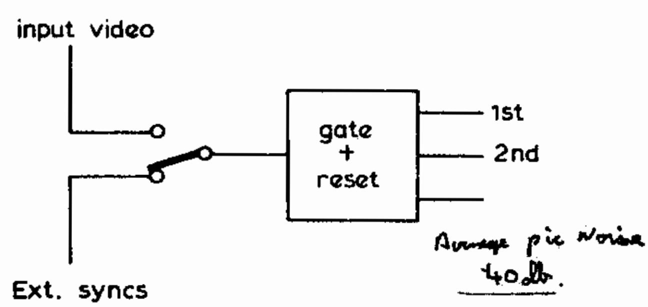
lift waveform to measure the active picture noise of picture origination equipment. It can only measure noise above about 200kHz, i.e. mainly random noise.









P.J. Harris/VC
18th February 1981