APPLICATION NOTE 25

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CATHODE RAY TUBE PHOSPHORS AND THE INTERNAL GRATICULE CATHODE RAY TUBE

Recent developments in CRT phosphors as well as refinements in aluminizing have lead to greater brightness, clarity, increased photographic writing rates and improved resistance of the phosphors to burning. Now, more than ever, using the correct phosphor in any particular measurement application significantly improves the overall performance of an oscilloscope.

This publication lists the types of phosphors available for hp oscilloscopes (Table 1) and reviews the basic characteristics of the more important CRT phosphors (Table 2). Table 2 gives you an overall view of various phosphor types so that you can quickly determine which phosphor best fits your particular application. A complete Appendix defines and explains each of the phosphor characteristics which appear in Table 2.

In addition, the construction and advantages of the internal graticule feature of some hp CRT's are described. Finally, important details on the aluminizing feature incorporated in many hp CRT's are covered.

Each oscilloscope in the hp line may be fitted with the standard phosphor or with an optional phosphor listed in Table 1. Table 1 lists each hp oscilloscope along with its CRT type, acceleration voltage and its standard and optional phosphors.

The standard phosphor provides you with an optimum trace for visual observation of normal repetitive signals. Each standard phosphor is chosen for its superior combination of favorable trace color, trace to phosphor background contrast and brightness. The standard phosphor is automatically delivered with your hp oscilloscope unless you specify an optional or special phosphor.

Optional phosphors are available for special oscilloscope applications. For example, where photographic applications predominate or low duty cycle phenomenon are to be observed, a P7 or P11 phosphor may be preferred. Almost all specialized phosphor requirements can be met by the optional phosphors listed in Table 1. These optional phosphors are available on request at little or no increase in cost or delivery time.

PHOSPHOR CHARACTERISTIC CHART (Table 2)

The numerical and descriptive material presented in Table 2 is based either upon tests of cathode ray tubes produced at Hewlett-Packard or is extracted from data provided by the manufacturers of phosphors. Though these figures for a phosphor may vary somewhat from tube to tube, they are valid for making order-of-magnitude comparisons between the phosphor types listed. Significant variations may exist between the brightness, writing rate, and burn resistance data given on the chart and data based upon CRT types of a different manufacturer. These variations

Table 1. Standard and Optional Phosphors for hp Oscilloscopes

Model	CRT Type	Acc. Volts	Phosphor*		Int. Graticule**
			Std.	Optional	
120A	5AQ	2.5 kv	P1	P2, P7, P11AL	kit
120B	G203	2.5 kv	P31	P2, P7, P11AL	std
130B	5AQ	3 kv	P1	P2, P7, P11AL	opt 3 or kit
150A	5AM	5 kv	P31AL	P2, P7AL, P11AL	opt 3 or kit
160B	5AM	5 kv	P31AL	P2, P7AL, P11AL	opt 3 or kit
170A	5BH	10 kv	P31AL	P2AL, P7AL, P11AL	opt 3 or kit
185A	5AQ	3 kv	P1	P2, P7, P11AL	kit
185B	5AQ	3 kv	P2	P1, P7, P11AL	opt 3 or kit

* AL indicates aluminized CRT.
** Not available with P1; use P31 which has characteristics similar to P1.

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Table 2. Characteristics of Common Phosphors in hp Cathode Ray Tubes
(Figures are approximate. See Appendix for definitions and explanations)

Phosphor	Trace Color Under Excitation	Trace Color After-Glow	Low Level Persistence	Writing Rate (aluminized 5BH at 10 kv)	Relative Burn Resistance	Relative Visual Brightness 5AQ 2.5kv	Relative Visual Brightness 5AM 5kv	Relative Visual Brightness 5BH 10kv	Trace Contrast (without filter)
P1	green	green	180 ms	200 cm/μs	100	100	600	3000	good
P2	blue	yellow	1 sec	600 cm/μs	150	90	550	2000	fair
P7	blu-wht	yellow	3 sec	200 cm/μs	75	50	400	1500	poor
P11	blue	blue	20 ms	700 cm/μs	75	20	200	800	poor
P31	blu-grn	lt grn	0.5 sec	400 cm/μs	250	110	1300	5000	fair to poor

Phosphor	Phosphor Application	Advantages	Disadvantages
P1	General purpose phosphor for visual observation of repetitive signals	Good trace to background contrast; color near center of visual spectrum.	Lack of persistence; color too yellow for fast writing rate photography.
P2	General purpose phosphor for visual and photographic observation of slow and normal repetitive signals.	Persistence characteristic may be intensified with an amber filter; short persistence bluish trace very good for photography.	Low trace to background contrast; trace brightness lower than P1 and P31.
P7	For observation of low repetition rate and non-repetitive phenomena.	Very long persistence; wide spectral separation between blue and yellow so that filters may emphasize either characteristic.	Specialized characteristics limit general use.
P11	For photographing all signal types, particularly those requiring fast writing rate.	Blue trace color near maximum sensitivity of film.	Specialized characteristics limit its general use.
P31	General purpose phosphor for visual and photographic observation of repetitive signals.	Provides highest visual brightness - particularly at 5 kv and above in aluminized tubes; listed characteristics combine to make it a good general purpose phosphor.	Low trace to background contrast under bright ambient light conditions.

depend principally upon 1) CRT characteristics 2) amount of phosphor used; phosphor grain size 3) source manufacturer of phosphor and 4) the methods and techniques used in applying the phosphor to the CRT.

ADDITIONAL CRT FEATURES

Internal Graticule - The internal graticule is applied to the inside of the CRT face plate in the same plane as the phosphor layer. In this way the parallax error* which is unavoidable in conventional CRT's is completely eliminated.

As opposed to many conventional tubes, a tinted filter is not used with internal graticule CRT. Instead, a non-reflective glass face plate is bonded to the CRT face plate. Such an arrangement virtually eliminates the sharp distracting reflections which are commonly observed on the surface of a conventional face plate-filter combination, provides a brighter trace and reduces the hazard of implosion.

Since parallax is absent in this tube all waveform measurements are easier, and more accurate. Rise time, pulse width and signal amplitude measurements are greatly simplified. Trace photographs which usually have about a 4% time base parallax error are also more accurate with the internal graticule CRT. Since you can make accurate trace measurements from oblique angles, it is no longer necessary to place the oscilloscope directly in front of an operator. Hence, an internal graticule affords greater convenience and flexibility when arranging rack-mounted equipment.

Availability of the Internal Graticule CRT - The internal graticule CRT is standard equipment for the ⓗ Model 120B Oscilloscope and is optional (Option 3) for ⓗ Models:

122A Dual Trace Oscilloscope	dc to 200 kc
130B Oscilloscope	dc to 300 kc
150A Oscilloscope	dc to 10 mc*
160B Oscilloscope	dc to 15 mc*
170B Oscilloscope	dc to 30 mc*
185B Oscilloscope	dc to 800 mc*

* Uses plug-in amplifiers

In addition, field modification kits are available for the listed oscilloscopes, for ⓗ Model 120A Oscilloscope (dc to 200 kc) and ⓗ Model 185A Oscilloscope (dc to 800 mc). For further modification kit information contact: Customer Service Department, Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, California.

ALUMINIZED CRT'S

In aluminized CRT's, a very thin layer of aluminum is atomized over the phosphor. This aluminum layer is thin enough to allow the electron beam to reach the phosphor. Aluminizing increases the trace brightness of the phosphor by reflecting a large part of the phosphor light output which is ordinarily lost to the interior of the CRT. Beyond increasing brightness, the aluminum protects the more fragile phosphors against burning.

Aluminizing produces significant increases in the trace brightness of all phosphors at accelerating voltages of 5 kv and above. It typically increases the intensity of P31 about 2-1/2 fold at 5 kv and about 3-1/2 fold at 10 kv.

In CRT's with acceleration voltages of less than 5 kv, 5AQ's for example, aluminizing causes little net increase in trace brightness because the beam energy loss which occurs as the beam penetrates the aluminum is a significant part of the total kinetic energy of the beam. As the beam energy increases (higher accelerating potential) the energy loss decreases in significance. For this reason all standard phosphor ⓗ 5AM and 5BH CRT's are aluminized, while 5AQ tubes are not. An exception is 5AQ tubes with P11 where it is fruitful to aluminize because the small intensity gain is valuable in the photographic applications for which the phosphor is used.

* See ⓗ Journal Vol. 12 No. 11 for an analysis of the parallax error in conventional CRT's.

APPENDIX

EXPLANATION OF PHOSPHOR CHARACTERISTICS IN TABLE 2

The following section provides definitions and descriptions of the various phosphor characteristics enumerated across the top of Table 2 and gives some detail on the data presented. To facilitate cross reference from this text to the chart, the numbered headings used in this section are the same as those used in Table 2.

1. TRACE COLOR -

a) Under Excitation - This is the color of the light which the phosphor emits when it is being excited by the electron beam.

b) Afterglow - After the excitation of the beam is removed, most phosphors continue to emit light, a phenomenon called afterglow. The color of the afterglow is given.

2. LOW LEVEL PERSISTENCE -

After beam excitation some phosphors glow for mere milliseconds while others release light for longer times. The eye, which has a logarithmic sensitivity, can detect the low level afterglow of these phosphors, if the trace is viewed in the darkness provided by a CRT hood. Such long persistence phosphors make it possible to observe low repetition rate (less than 1 cps) signals or even single shot transients.

The time measurements on the chart indicate the time period required for the afterglow of the phosphor to decrease in intensity from 100% (just after beam excitation is removed) to 0.01% - a level of light intensity which is still quite visible to the eye.

3. PHOTOGRAPHIC WRITING RATE -

Measurement of the maximum spot speed which can be adequately photographed is an index of the effectiveness of a phosphor for use in the recording of high-speed phenomena. A high writing rate is necessary for photographing fast rise time single shot and low repetition rate phenomena. Besides being dependent upon the phosphor type used, the writing rate is also a function of 1) CRT type, acceleration voltage and scope settings and 2) photographic equipment - camera, film speed and lens settings.

The usual method for measuring writing rate is to apply a single shot damped sine wave to the oscilloscope; the frequency is such that the vertical component of signal change (dy/dt) as viewed on the CRT is more than 10 times faster than the horizontal sweep (dx/dt) used in the measurement. In other words the maximum slope of the signal (dy/dt) should be greater than ten so that the writing rate (beam spot speed) may be assumed to equal dy/dt. In addition, the first few cycles of the signal should be of sufficient amplitude that they are not completely photographed on the film used.

Under these conditions writing rate is defined as: $v = \pi fd$ where f is the frequency of the damped sine wave and d is the peak-to-peak amplitude of the first vertical excursion of the signal which is photographed in its entirety. Since the contrast of a writing rate photograph is often poor, it is difficult to determine which excursion should be used for the determination of "d". For this reason, variations in writing rate measurements of 25% may occur in tests on the same CRT.

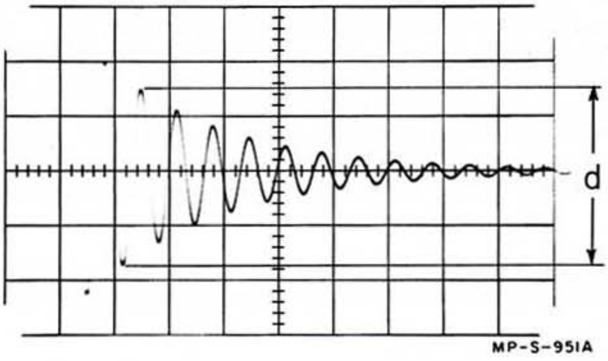

Figure 1. Photograph of a 15 mc damped sine wave used in the calculation of writing rate. (Scope settings: 0.1 μsec/cm, 0.5 volts/cm)

The damped sine wave in figure 1 yields a writing rate of (3.14) (15 cycles/μsec)(2.8 cm) = 132 cm/μsec.

Table 2 gives the approximate writing rates of the various aluminized phosphors in 10 kv (5BHP) tubes. These measurements were made with ASA 3000 film in an hp 196A Oscilloscope Camera set at F1.9 and "bulb"; presensitizing techniques were not used.

4. BURN RESISTANCE -

The heat from an intense well focused electron beam, held in one spot on the phosphor for a time, can reduce the luminous efficiency or fluorescence of the area (dark burn). There will be gaps in a trace which crosses dark burned areas. Large burn areas ruin a CRT.

As is shown in these purely relative numerical expressions of resistance to dark burn (where P1's resistance is arbitrarily set at 100 as a basis for comparison), the different phosphors vary in their burn resistances. Thus, in applications where P7 and P11 are needed and the likelihood of phosphor burning is high, it is wise to use an aluminized CRT for the aluminum effectively reduces the heat concentration which might otherwise damage the phosphor.

5. VISUAL BRIGHTNESS -

This is simply an expression of relative trace brightness at the indicated acceleration voltages under equivalent test conditions. These figures refer to non-aluminized phosphors at 2.5 kv (in 5AQ tubes) and aluminized phosphors at 5 kv and 10 kv (in 5AM and 5BH tubes). The brightness level of non-aluminized P1 at 2.5 kv was arbitrarily set at 100.

6. CONTRAST -

The level of contrast of a trace is a function of the color difference between the trace and background provided by the phosphor as well as the brightness level of the trace itself. Since this is a very difficult factor to measure, descriptive terms have been used to indicate the comparative contrasts of the phosphors when visually observed without using any kind of filter in front of the CRT face. Filters of green, amber and blue may be used to increase contrast.