List of Publications by the Author

1. Patel, K. S., "A Comparative Study of the Performance of a Class-C Harmonic Generator with Fractional Sine Wave, Isosceles Triangle and Rectangular Pulse Drives", J. Inst. Telecom. Engrs., Vol. 8, No. 6 (1962), 298-305.

2. Banerjee, B. M. and Patel, K. S., "General Purpose Diode Voltmeters", Electro-Technology, Vol. 3, No. 5 (1959), 193-195.

3. Patel, K. S., "Theory, Design and Performance of a Conventional Frequency Multiplier using a Pulse Drive" (To be Communicated).

A COMPARATIVE STUDY OF THE PERFORMANCE OF A CLASS C HARMONIC GENERATOR WITH FRACTIONAL SINE WAVE, ISOSCELES TRIANGLE AND RECTANGULAR PULSE DRIVES

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A COMPARATIVE STUDY OF THE PERFORMANCE OF A CLASS C HARMONIC GENERATOR WITH FRACTIONAL SINE WAVE, ISOSCELES TRIANGLE AND RECTANGULAR PULSE DRIVES

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Abstract

The full sine wave drive to a class C harmonic generator is limited at the most to the fourth or fifth order harmonic, because of the limitations in the driving power. The rectangular pulse drive through a wide band circuit, as proposed here by the author, however, does not suffer from these disadvantages. In such a system, generation of harmonics higher than the fifth order is practical. The performance of such a generator is calculated out in terms of $(C_n)_{opt}$, $(d/T)_{n\ critical}$ and $(A_{av})_n$, i.e. the values of the harmonic amplitude, angle of flow and the d.c. value of plate current in the optimum case. The $(d/T)_{n\ critical}$ is inversely proportional to the harmonic number n and $(C_n)_{opt}$ and $(A_{av})_n$ are also similarly related. The calculations extended to the case of fractional sine wave and isosceles triangle pulse waveforms show similar relation between the parameters. Besides, the ratio

$$\left[\frac{(C_n)_{opt}}{(A_{av})_n}\right]$$

remains sensibly constant and independent of harmonic number for the three pulse waveform drives. This means that the efficiency of harmonic conversion from d.c. is constant for all harmonics in the optimum condition. Finally, the relative merits of each drive are discussed. Full sine wave drive voltages for different (d/T) ratio for the tube type QQE 06/40 is also given for comparison.

Introduction

CLASS C harmonic generators are used in high frequency transmitters for frequency multiplication. The drive source of these harmonic generators or the so-called frequency multipliers is usually the sinusoidal oscillation from a master oscillator controlled by a crystal. The performance of these class C harmonic generators with reference to a full sine wave drive was studied in great details by Terman.[1] He reported it to be limited to the 4th or at the most the 5th order harmonic.

The higher order harmonics require correspondingly smaller angle θ_p of the plate current flow.† Furthermore, the exciting power required by a harmonic generator becomes greater as θ_p becomes smaller, and increases rapidly with the order of the harmonic. Now, since the available drive is usually limited, this means that with higher harmonic multiplication, the power output becomes smaller. Because of this, frequency multiplication higher than the 4th or 5th with single stage is usually impracticable.

Rectangular pulse waveform drive — In this paper, a rectangular pulse drive as can be conveniently supplied by a blocking oscillator has been proposed. This appears attractive because the harmonic generator then requires a grid bias only slightly greater than cut off. So the driving power required for generating a particular harmonic is small. Generation of a high order harmonic requires a suitably small pulse duration. Practical realization of desired aims in this direction has been made possible by the development of wide band transformers and secondary emission pentodes.

General plan of work — In the present work, the performance of the generator in terms of a rectangular pulse waveform drive

†The value of the angle of flow calculated out in the optimum case is found to decrease in inverse proportion (FIG. 4) to the order of the harmonic.

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was first studied theoretically with the help of the Fourier analysis method. Later, the study was extended to two other repeating pulse drives, viz. (i) fractional sine wave pulse drive, (ii) isosceles triangle pulse drive.

It is of considerable interest to note that the optimum amplitude, $(C_n)_{opt}$, of a harmonic is achieved only for a certain critical value of the duration of the plate current pulse, $(d/T)_{n\ critical}$. In the following section, the values of these two parameters for all harmonics up to the 15th, together with the corresponding d.c. components of the current pulses, have been calculated out and tabulated (Table II).

Subsequently, a comparison is made of the harmonic amplitude and the d.c. plate current calculated out in the optimum case, for fractional sine wave and isosceles triangle pulse drives, with those for rectangular pulse drive. The results of the calculations (Table II) further have been presented in the form of some suitable ratios for easy comparison.

Lastly, relative merits and demerits of the three types of drives have been interpreted from the results tabulated as well as shown graphically. Besides, some salient features of the calculation have also been brought out and discussed.

Assumptions — The peak current flow in the tube is assumed one ampere and the angle of plate current flow (measured in terms of the period of a wave) is assumed the same for each drive.

Calculations

Fourier analysis of pulse waveforms — The frequency spectrum of a recurrent waveform can be represented by the following Fourier series:

$$f(t) = A_{av}+\sum_{n=1}^{\infty} A_n \cos n\omega_p t+B_n \sin n\omega_p t$$

$$= A_{av}+\sum_{n=1}^{\infty} C_n \sin (n\omega_p t+\phi). \qquad \dots(1)$$

where

$$A_{av} = \frac{1}{T}\int_0^T f(t)\, dt \qquad \dots(2)$$

$$C_n = \sqrt{A_n^2+B_n^2} \qquad \dots(3)$$

$$A_n = \frac{2}{T}\int_0^T f(t) \cos \frac{2\pi nt}{T} dt \qquad \dots(4)$$

$$B_n = \frac{2}{T}\int_0^T f(t) \sin \frac{2\pi nt}{T} dt \qquad \dots(5)$$

A_{av} and C_n in Eqs. (2) and (3) denote respectively the d.c. component of the pulse and the magnitude of the nth harmonic.

The values of these two $[A_{av}, C_n]$ Fourier coefficients as obtained by Eqs. (2) and (3), for the three repeating plate current pulses of Fig. 1, are represented in Table I.

TABLE I — FOURIER COEFFICIENTS (A_{av}, C_n) OF THE PULSE WAVEFORMS[2] OF FIG. 1

Type of current pulse waveform	A_{av}	C_n
Fractional sine wave	$\dfrac{A\left(\sin \frac{\pi d}{T} - \frac{\pi d}{T}\cos \frac{\pi d}{T}\right)}{\pi\left(1-\cos \frac{\pi d}{T}\right)}$	$\dfrac{A_{av}\left(\frac{\pi d}{T}\right)}{n\left(\sin \frac{\pi d}{T} - \frac{\pi d}{T}\cos \frac{\pi d}{T}\right)}\left[\dfrac{\sin (n-1)\frac{\pi d}{T}}{(n-1)\frac{\pi d}{T}} - \dfrac{\sin (n+1)\frac{\pi d}{T}}{(n+1)\frac{\pi d}{T}}\right]$
Isosceles triangle	$A\left(\frac{d}{2T}\right)$	$2A_{av}\left[\dfrac{\sin (n\pi d/2T)}{(n\pi d/2T)}\right]^2$
Rectangular	$A\left(\frac{d}{T}\right)$	$2A_{av}\left[\dfrac{\sin (n\pi d/T)}{(n\pi d/T)}\right]$

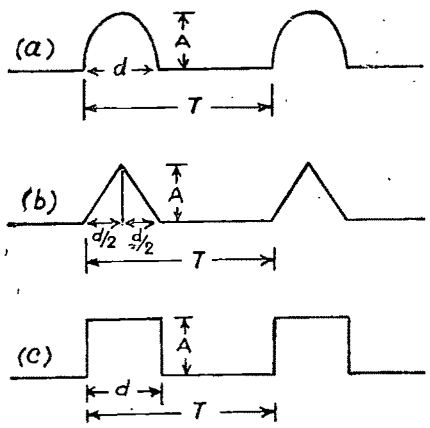

FIG. 1 — (a) FRACTIONAL SINE WAVE, (b) ISOSCELES TRIANGLE AND (c) RECTANGULAR CURRENT PULSE WAVEFORMS; EACH OF WIDTH d, PERIOD T AND AMPLITUDE A

Definitions of $(C_n)_{opt}$ *and* $(d/T)_{n\,critical}$ — The numerical calculations of the amplitude of a harmonic of a typical pulse form of Fig. 1, carried out point by point for different fractional period (d/T) of flow by the formula listed in Table I, give result of considerable practical interest. It is to be noted that the peak amplitude of a harmonic $(C_n)_{opt}$ occurs only for a certain critical value (see Fig. 2) of the angle $(d/T)_{n\,critical}$ of the plate current flow.

The values of these two parameters $[(C_n)_{opt}, (d/T)_{n\,critical}]$ have been determined for all harmonics up to the 15th of the pulse waveforms of Fig. 1, together with $(A_{av})_n$ — the d.c. values of the current, with pulse of width $(d/T)_{n\,critical}$, by the method given below.

Calculations of the optimum values of (C_n) *and* $(d/T)_n$ — In this section, a method of calculating $(C_n)_{opt}$ and $(d/T)_{n\,critical}$ for the pulse waveforms of Fig. 1 has been worked out and illustrated. It consists in determining first the critical value of (d/T) for a harmonic, which satisfies equation

$$\frac{d}{d(d/T)}\left[C_n\right] = 0$$

The substituting of this value of (d/T), i.e. $(d/T)_{n\,critical}$ in the expression for (C_n), gives its optimum value $(C_n)_{opt}$.

(a) *Isosceles triangle pulse waveform* — We have

$$(C_n) = 2A(d/2T)\left[\frac{\sin n\pi(d/2T)}{n\pi(d/2T)}\right]^2$$

or

$$= 2\frac{\sin^2 n\pi x}{n^2\pi^2 x} \quad [A=1 \text{ amp., } d/2T=x] \quad (6)$$

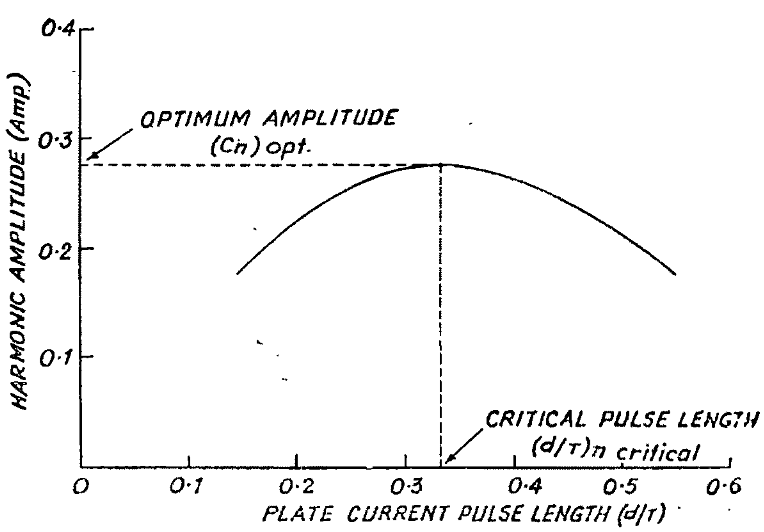

FIG. 2 — AMPLITUDE OF A HARMONIC ($n=2$) AS A FUNCTION OF THE ANGLE OF PLATE CURRENT FLOW (d/T)

For C_n to have a maxima, $\left(\frac{dC_n}{dx}\right) = 0$

$$\text{or} \quad \tan n\pi x = 2n\pi x \qquad \ldots(7)$$

Let $x = x_n$ be the solution of Eq. (7), then

$$\tan n\pi x_n = 2n\pi x_n \qquad \ldots(8)$$

Substituting the value $x = x_n$ in Eq. (6), we get

$$(C_n)_{opt} = \frac{8x_n}{1+4n^2\pi^2x_n^2} \qquad \ldots(9)$$

The value of x satisfying Eq. (7), i.e. $x = (d/2T)_{critical}$, can be found out for any number of harmonics, from the tables of natural tangents. Thus Eqs. (7) and (9) together determine the optimum values of C_n for the harmonics.

Eq. (7) has been solved for different values of n (harmonic number), its solutions (in terms of x_n) have been found to follow a relation

$$x_n = \left(\frac{x_1}{n}\right) \qquad \ldots(10)$$

where $x_1 = 0{\cdot}371$ denotes the critical angular width of the fundamental. Substituting the value of x_n in Eq. (9) gives

$$(C_n)_{opt} = \frac{(C_1)_{opt}}{n} \qquad \ldots(11)$$

$$= \frac{0{\cdot}46132}{n}\ \text{amp.} \qquad \ldots(12)$$

where $(C_1)_{opt} = 0{\cdot}46132$ amp. denotes the optimum amplitude of the fundamental.

The values of $(C_n)_{opt}$ and $(d/T)_{n\,critical}$ can thus be found out in a straightforward manner from Eqs. (10) and (11). The computation of the preceding example repeated for rectangular and fractional sine wave pulse waveforms (FIG. 1) give the value of $(C_n)_{opt}$ and $(d/T)_{n\,critical}$ as represented in Table II.

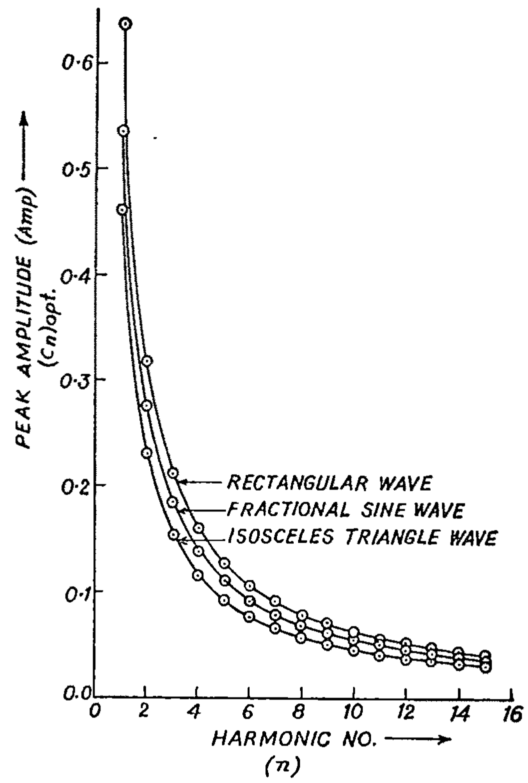

FIG. 3 — OPTIMUM AMPLITUDE OF A HARMONIC AS A FUNCTION OF HARMONIC NUMBER FOR PULSE WAVEFORMS OF FIG. 1

(b) *Presentation of results and conclusions* — The data represented in Table II are plotted in Figs. 3, 4 and 5.

Two conclusions can be drawn easily from Table II.

First, the parameter $(C_n)_{opt}$ as well as $(d/T)_{n\,critical}$ decreases in inverse proportion

TABLE II — PLATE CURRENT PULSE LENGTH AND HARMONIC AMPLITUDE IN HARMONIC GENERATOR WITH CURRENT PULSES OF FIG. 1

PULSE WAVEFORM	$(d/T)_n$ critical	$(C_n)_{opt}$ AMP.	$(A_{av})_n$ AMP.
Fractional sine wave	0·681 (for $n=1$) 0·663/n (for $n>1$)	0·53646 (for $n=1$) 0·55496/n (for $n>1$)	0·41269 (for $n=1$) 0·4423/n (for $n>1$)
Isosceles triangle	0·745/n	0·46132/n	0·3725/n
Rectangular	0·500/n	0·63663/n	0·5000/n

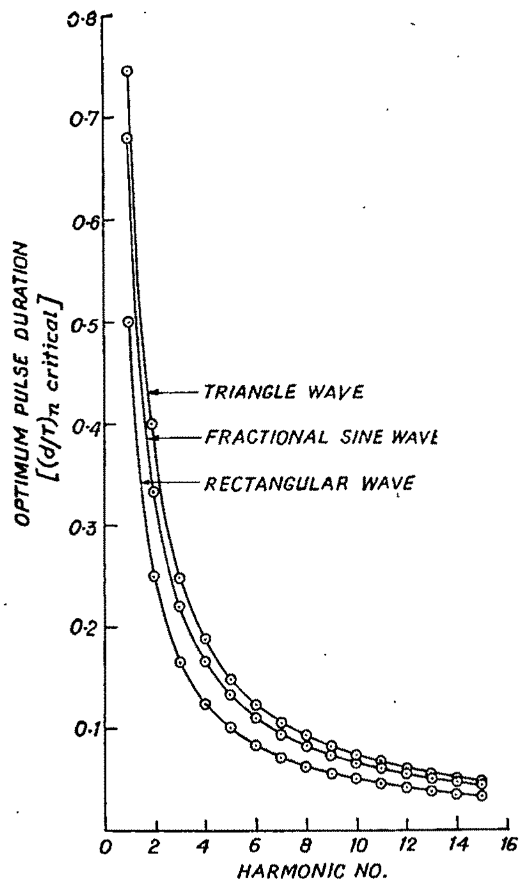

FIG. 4 — CRITICAL ANGULAR WIDTH OF THE PLATE CURRENT FLOW AS A FUNCTION OF THE HARMONIC NUMBER FOR PULSE WAVEFORMS OF FIG. 1

to the order of the harmonic, for any one of the plate current pulse waveforms of Fig. 1 (see Figs. 3 and 4).

Secondly, as indicated in Fig. 2, the optimum amplitude for a given harmonic order n, $(C_n)_{opt}$, is obtained only with a particular angle of plate current flow $(d/T)_{n\ critical}$. In addition, the values of these two optimum parameters thus obtained for a harmonic depend on its harmonic number n and are also inversely related to it. This means that the ratio of these two parameters for a harmonic, in the optimum case, has a maximum value that is unique for all other harmonics of a particular pulse waveform. This is represented in Fig. 5 by straight lines.

A very interesting result also follows from a close examination of Table II.

It is seen that the peak amplitude of the fundamental of the pulse waveforms of Fig. 1 occurs only for the pulse of the plate current lasting for half a cycle in case of rectangular pulse and *greater than half a cycle* in the cases of triangle and fractional sine wave pulse forms.

This means that the maximum power output, in the cases of fractional sine wave and triangle pulse drives, *is not obtained* by running the tube in the conventional class B condition. It occurs at the value of grid bias a few volts smaller than the cut-off bias. The class B operation ensures the maximum ever attainable power output only in the case of a rectangular pulse drive.

Comparison of Results and Discussions

Forms of ratios — It is extremely interesting to present the results obtained so far (Table II) in the form of ratios

$$\frac{(C_n)_{opt}}{(A_{av})_n}, \quad \frac{(C_n)_{opt\,(R.)}}{(C_n)_{opt\,(F.S.)}}, \quad \frac{(C_n)_{opt\,(R.)}}{(C_n)_{opt\,(I.T.)}},$$

$$\frac{(d/T)_{n\ critical\,(F.S.)}}{(d/T)_{n\ critical\,(R.)}} \quad \text{and} \quad \frac{(d/T)_{n\ critical\,(I.T.)}}{(d/T)_{n\ critical\,(R.)}}$$

These ratios are obtained by comparing the results obtained for fractional sine wave (F.S.) and isosceles triangle (I.T.) pulse waveforms, with the results of rectangular pulse waveform (R.) and are represented in Table III.

Interpretations of various plots — An inspection of the curves of Figs. 3, 4 and 5 gives some interesting general conclusions.

The major part of the fall in amplitude, up to 80 per cent of the fundamental in $(C_n)_{opt}$ as well as $(d/T)_{n\ critical}$, occurs in the generation of the harmonics up to the 5th, additional falls up to 10 per cent and 3·3 per cent of the fundamental ocur in the generation of the harmonics up to the 10th and 15th.

Further, it is also apparent from Table III that optimum amplitude available for any harmonic $(C_n)_{opt}$ in the case of a harmonic generator with drive Nos.* 1 and 3 is

*Numbers 1, 2 and 3 signify fractional sine wave, rectangular and isosceles triangle pulse waveforms.

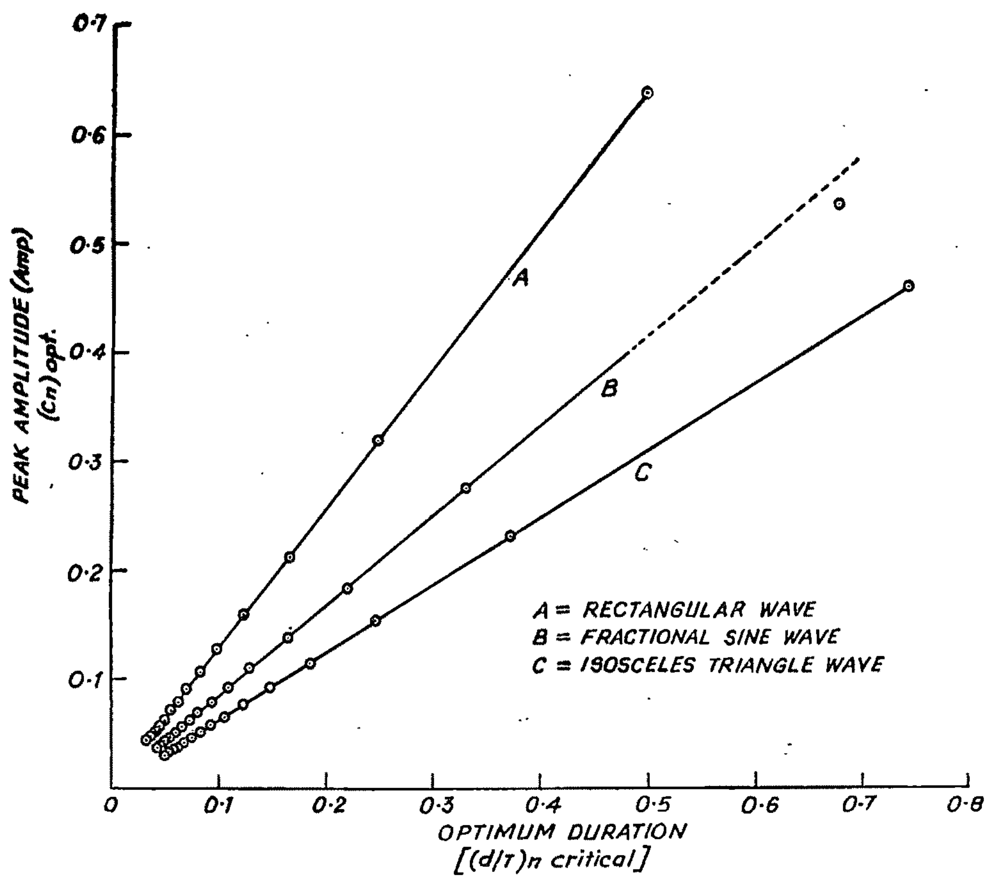

Fig. 5 — Optimum amplitude of a harmonic and critical angular width of the plate current flow. The circles on the plots, from right to left, indicate the harmonic number starting from the fundamental

decreased by constant factors (independent of the harmonics), α and β, of 1·15 (approx.) and 1·38; whereas the critical angular width $(d/T)_{n\ critical}$, required of the plate current pulses, with the same drives, to achieve for the individual harmonics, is increased by another set of constant factors (independent of harmonics), γ and δ, of 1·33 and 1·49; the case under comparison is that of a generator with drive No. 2. This indicates that although the rectangular pulse waveform drive offers marked improvement (by factors of 1·15 and 1·38) in the harmonic amplitude, it requires comparatively the shorter (factors of 1·33 and 1·49) length of the plate current pulses than in the two other cases of drive (Table III).

Relation between plate current pulse form and plate efficiency — In general, the flattening of the top portion of the pulse form shortens the length of the current pulse required to generate the optimum amplitude for a particular harmonic. It also increases the magnitude of the optimum amplitude and results in increased plate efficiency

$$\left[\frac{(C_n)_{opt}}{(A_{av})_n}\right]$$

By far the most important outcome of the present investigation is that the ratio

$$\left[\frac{(C_n)_{opt}}{(A_{av})_n}\right]$$

TABLE III

Harmonics n	$[(C_n)_{opt}]/[(A_{av})_n]$ F.S.	I.T.	R.	α	β	γ	δ
1	1·3015	1·2384	1·2733	1·1863	1·3797	1·3600	1·490
2	1·2640	1·2384	1·2733	1·1545	1·3797	1·3340	1·490
3	1·2629	1·2384	1·2733	1·1497	1·3797	1·3206	1·490
4	1·2614	1·2384	1·2733	1·1480	1·3797	1·3240	1·490
5	1·2550	1·2384	1·2733	1·1473	1·3797	1·3330	1·490
6	1·2541	1·2384	1·2733	1·1468	1·3797	1·3321	1·490
7	1·2604	1·2384	1·2733	1·1468	1·3797	1·3329	1·490
8	1·2587	1·2384	1·2733	1·1468	1·3797	1·3328	1·490
9	1·2581	1·2384	1·2733	1·1461	1·3797	1·3177	1·490
10	1·2616	1·2384	1·2733	1·1580	1·3797	1·3200	1·490
11	1·2551	1·2384	1·2733	1·1468	1·3797	1·3250	1·490
12	1·2579	1·2384	1·2733	1·1463	1·3797	1·3319	1·490
13	1·2544	1·2384	1·2733	1·1463	1·3797	1·3259	1·490
14	1·2573	1·2384	1·2733	1·1461	1·3797	1·3272	1·490
15	1·2510	1·2384	1·2733	1·1462	1·3797	1·3350	1·490

$\alpha = \frac{(C_n)_{opt\,(R.)}}{(C_n)_{opt\,(F.S.)}}$ $\beta = \frac{(C_n)_{opt\,(R.)}}{(C_n)_{opt\,(I.T.)}}$ $\gamma = \frac{(d/T)_n\ critical\ (F.S.)}{(d/T)_n\ critical\ (R.)}$ $\delta = \frac{(d/T)_n\ (critical\ (I.T.)}{(d/T)_n\ critical\ (R.)}$

in the optimum case, is constant and independent of the harmonics for any one of the plate current pulse waveforms of Fig. 1 (hence, of course, of the drive voltages). Further, its values calculated out for drives of three totally different shapes (Table III) do not seem to differ very appreciably (see Fig. 6) from one another, so that one need not be too careful in obtaining an exact shape of a particular pulse form. An overall shape of the driver waveform approximating to the exact one desired will produce essentially the same results.

Typical example — The test of the particular choice of the drive voltage waveform, i.e. the drive No. 2, has been carried out for a typical tube type QQE 06/40. The results are listed in Table IV.

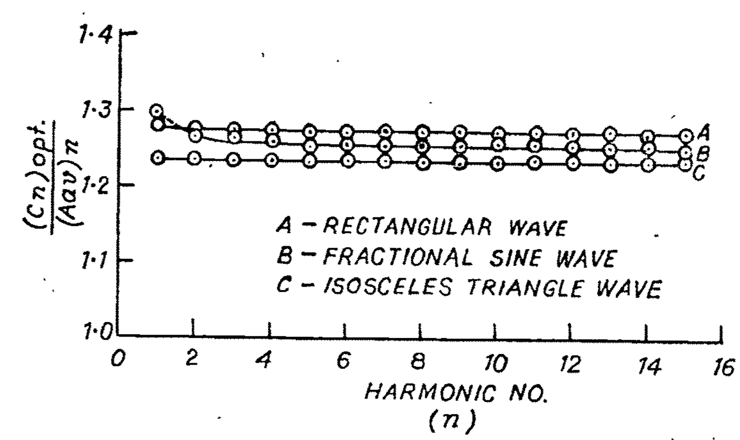

FIG. 6 — RATIO $[(C_n)_{opt}]/[(A_{av})_n]$ AS A FUNCTION OF THE HARMONIC NUMBER FOR PULSE WAVEFORMS OF FIG. 1

TABLE IV — PLATE CURRENT PULSE LENGTH AND EXCITING VOLTAGE* OF A HARMONIC GENERATOR WITH FULL SINE WAVE DRIVE

Pulse length (d/T)	Pulse length in electrical degrees (θ_p)	Grid bias required to achieve a desired angle of plate current flow (E_c) volts	Peak value of the exciting voltage required to produce an angle of plate current flow (E_g)† volts	Angle of grid current flow (θ_g)
1/2	180°	−30·48	48·48	102°20′
1/4	90°	−147·5	165·5	54°
1/8	45°	−619·0‡	637·0	27°37′
1/16	22·5°	−2561·0‡	2579·0	13°48′

*Calculated for QQE 06/04 ($\mu=8{\cdot}2$, $E_{sg}=250$ V., $E_{max}=18$ V.).
†$E_g=E_c+E_{max}$.
‡Maximum grid bias that can be applied is −175 V. only, hence these cases are beyond the scope of an experiment.

Note: For a rectangular pulse, the grid drive required to produce an angle (θ_p) of plate current flow is the same for all angles of flow and is equal to +48·5 V., this holds good also for pulse drives of fractional sine wave and triangle shapes.

Conclusions

The performance of a class C harmonic generator with reference to fractional sine wave, rectangular and isosceles triangle pulse waveform drives have been numerically computed out and interpreted in terms of some special parameters for all harmonics up to the 15th. Relative merits of each pulse waveform drive have also been indicated in this paper.

It has been found that the pulse drive method, as here proposed, offers, besides the advantages of higher harmonic output and plate efficiency, the possibility of operation at harmonic number of ten or greater than ten. The method has the advantage that the driver power requirements are small and the flexibility that the performance is not too critical of the actual shape of the drive waveform. Finally, the application of this system may lead to considerable simplifications in the design of aircraft transmitters and fixed tuned receivers operating on the V.H.F. band.

Acknowledgements

The author wishes to express his indebtedness to Sri B. M. Banerjee, Head of the Instrumentation Section, for suggesting the problem and for many helpful discussions.

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General Purpose Diode Voltmeters

B. M. BANERJEE AND K. S. PATEL

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General Purpose Diode Voltmeters

*B. M. Banerjee and *K. S. Patel

A diode rectifier directly working a $10\mu A$ meter, has many attractions over the more usual type utilizing a D.C. Amplifier indicating on a 200—1,000 μA meter. These are its simplicity, compactness and very stable zero adjustment. A circuit using an EA 50 diode is being used since 1955. This requires a heater supply of 6.3 volts at 150 mA which is supplied by a small 220/6.3 volts transformer. The balancing current is provided by small 1.5 volts dry cell. Later it was thought that an all dry cell unit would be more universal and a unit using a 1A3 diode requiring 150 mA at 1.4 volts for heater was developed. Both circuits have proved their reliability in continued use. The diode probes are small and separate and can be easily soldered to or hooked into the circuit. The indication will be only for the A.C. component, D.C. bias on the circuit point probed will have no effect. The scales are linear and the frequency response extends to more than 50 Mc/s for the 1A3 unit and 100 Mc/s for the EA50 unit. Actual capacity loading (3 pf for EA50 unit and 5 pf for 1A3 unit) will seldom be sensibly greater than the best commercial VTVM's available. The input resistance is however smaller, about 120,000 ohms for the EA50 unit and 200,000 ohms for the 1A3 unit. In the most sensitive range, full scale deflection is obtained at 3 volts for the EA50 unit and 5 volts for the 1A3 unit. (Fig. 1). Quick and reliable measurement of the R.F. voltages across resonant circuits can be made with these units, as are often needed in developmental work.

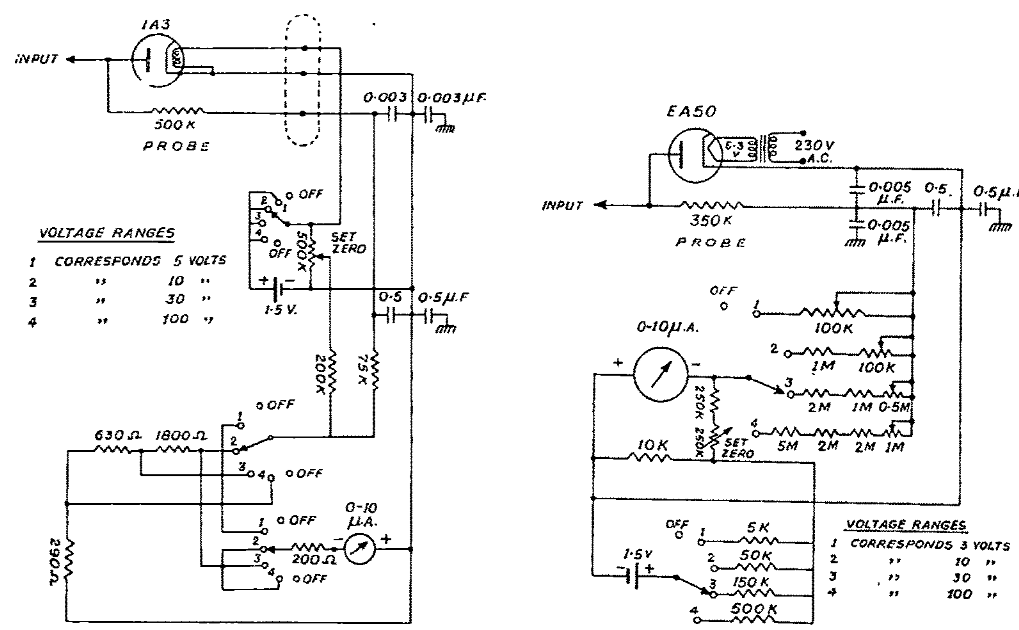

Fig. 1

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An inexpensive Crystal Diode Voltmeter was being used by the Instrumentation Section since 1953 in connection with measurements on frequency response of Delay Lines and Distributed Amplifiers. (Fig. 2). Continued application of this circuit for a variety of purposes, prompted some development work and the writing of this report. The instrument has been found to be very reliable. It has certain advantages over conventional vacuum tube voltmeters. These are the following :—

1. The indication with no input A.C. is a real zero current. Thus there cannot be any zero drift and the zero indication is as stable as that of the indicating moving coil meter. This makes possible quick and reliable measurements even in the lowest range of 0–0.4 volts r.m.s. Accuracy realized in actual measurements of small R.F. voltages will often surpass the best commercial vacuum tube voltmeters.
2. The input capacity is smaller than that of conventional V.T.V.M's. The Crystal + Resistor probe is smaller, lighter and can be soldered into the circuit. Actual capacity loading of the circuit probed will often be less than half of what a commercial V.T.V.M. harnessed to the job would produce.
3. The frequency response extends to over 50 Mc/s.
4. The scales are sensibly linear, even upto the smallest range, so that calibration charts need not be consulted in most measurements (Fig. 3).
5. The indication is for the A.C. and R.F. component only, any biasing D.C. that may be present at the point probed produces no indication.

The greatest drawback is the low input impedance which is as small as 15,000 ohms in the lowest range but increases to 40,000 ohms at the higher ranges. This however is of no consequence in measurements in which a nuclear physicist is most often interested, e.g., response characteristics of wide band amplifiers and net works.

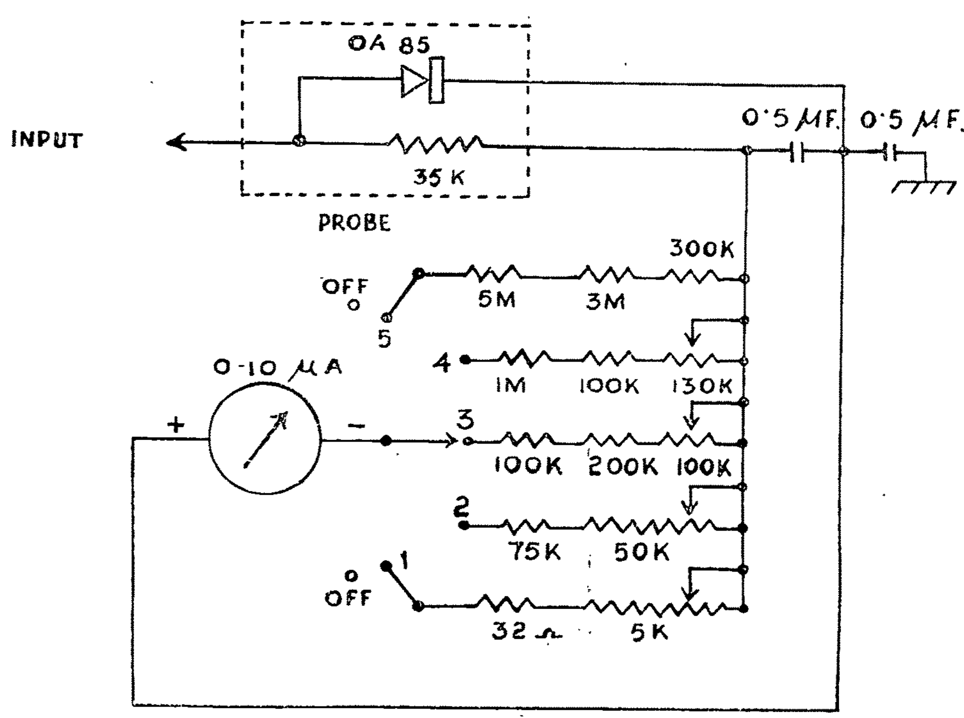
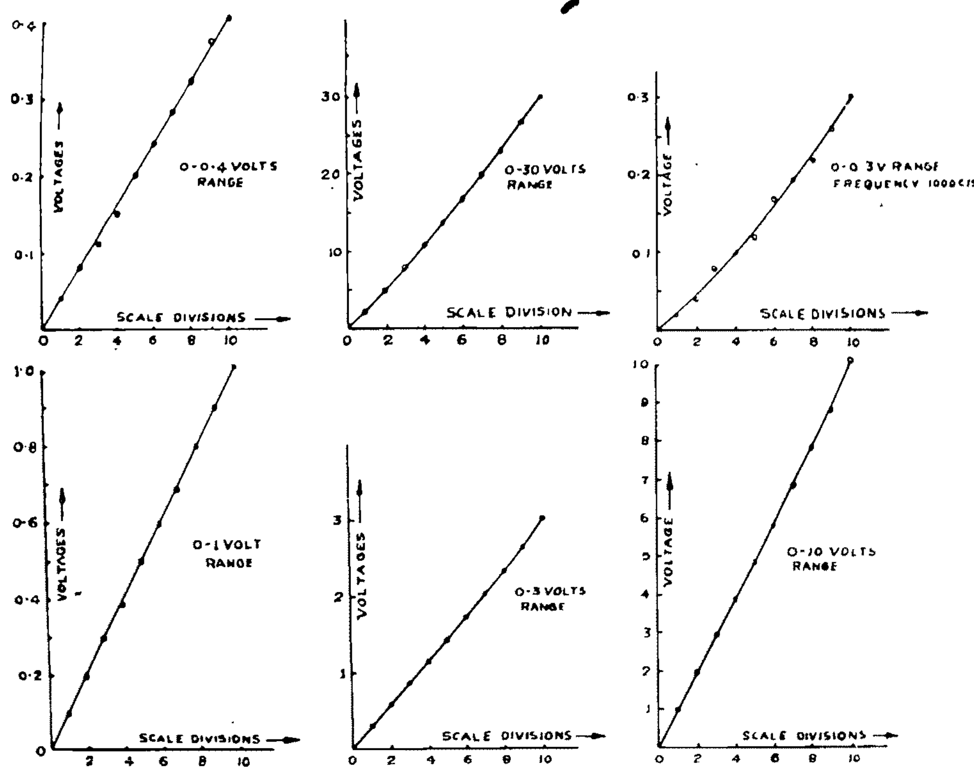


FIG. 2



CALIBRATION CURVES OF OA85 CRYSTAL DIODE VOLTMETER (AT FREQUECY = 1000 c/s)

FIG. 3

The other drawback is the relatively low maximum value (30 volts r.m.s.) of the input voltage that can be handled. Larger input voltages will eventually destroy the crytal diode.

When measuring in a circuit containing a D.C. bias of greater than 100 volts, care should be taken so that power is not switched on and switched off before the crystal diode or the voltmeter ground lead is removed. It is preferable to by-pass the crystal diode and resistor leads with smaller capacitors, (0.001 mfd) locally-on the circuit being measured, and to leave the ground lead of the voltmeter disconnected. Failure to observe this precaution will spoil the crystal diode. The 0.5 mfd capacities, within the voltmeter box are needed when the unit has to be calibrated with low frequency (50 c/s) A.C. ☐