論 文
35～12～7

非 高調波同調 플라이백 트랜스포머에 관한 研究

A Study on the Unharmonic-tuning Flyback Transformer

池 哲 根* · 朴 志 植**
(Chol—Kon Chee · Jee- Sik Park)

요 약

주사기간에 존재하는 링깅은 T. V 화면의 질(質)을 저하시킨다. FBT의 부유 리액턴스를 귀선 펄스의 고조파에 동조시킴으로서 링깅을 제거하는 방법이 소위 고조파 동조법이다. 그러나 손실이 있는 실제 FBT에서 링깅이 제로되는 조건을 구하여, 그 조건을 만족시키는 일은 많은 시간과 경험을 요구하게 된다.

이 논문에서는 손실이 포함된 FBT에 있어서 주사기간에 링깅이 제로가 되는 조건을 유도하고, 새로운 방법 즉, 비고조파동조법을 제안하였다.

Abstract

Ringing during the scan time deteriorates the picture quality of television receiver. By tuning the stray reactance of the flyback transformer(FBT) to harmonics of the retrace pulse, the ringing can be suppressed and this is, what is called, the harmonic tuning methed. But finding the conditions for the ringing to cease in lossy FBT and satisfying these conditions at design stage require much time and experience.

In this paper, the conditions for the ringing to cease in loss-included equivalent circuit are derived and a new method, unharmonic-tuning method, is suggested.

1. Introduction

Ringing appears when high voltage winding of FBT is shock-excited by retrace voltage. This ringing causes the deterioration of picture quality so that the FBT designers try to keep the ringing as small as possible during the scan time.

A lot of papers on FBT have been published.[1)~10)]

But most of them were performed under the assumption that the loss in FBT was negligible.[3)~10)] Recently there are some attempts to analyze the ringing in lossy FBT.[1),2)]

In this paper, a theoretical derivation of the conditions for the ringing to cease during the scan time and experimental investigation are performed by using the loss-included equivalent circuit. And the easier design method, unharmonic-tuning method, is discussed.

* 正 會 員 : 서울大 工大 電氣工學科 教授 · 工博
** 正 會 員 : 서울大 大學院 電氣工學科 博士課程
接受日字 : 1986年 6月 5日

2. Equivalent Circuit

A transformer, when considered as a four terminal network, can be represented by means of various equivalent circuits.[1),6)]

These two equivalent circuits shown in Fig. 1 are the simplified equivalent circuits of the FBT and horizontal output stages when C_m is negligible and can be obtained from Fig. A–2 and Fig. A–3 of appendix.

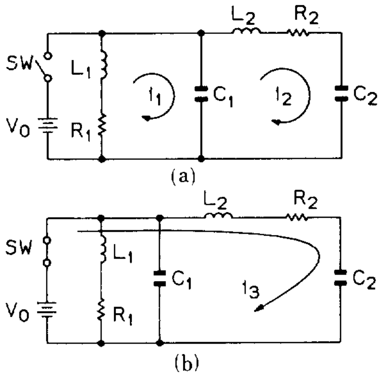


Fig. 1. Equivalent circuit of horizontal output and FBT stages.
(a) during the retrace period and
(b) during the trace period.

$$L_1=\frac{L_0 L_y}{L_0+L_y} \qquad L_2=L_0\left(\frac{1}{k^2}-1\right)$$

$$C_1=C_0+C_p \qquad C_2=N^2(C_s+C_e)$$

3. Theoretical Analysis of Ringing

3.1. Analysis of Retrace Period

From the equivalent circuit(Fig. 1–(a)), we obtain the following mesh equations.

$$\begin{bmatrix} R_1+L_1S+\frac{1}{C_1S} & -\frac{1}{C_1S} \\ -\frac{1}{C_1S} & R_2+L_2S+\frac{1}{S}\left(\frac{1}{C_1}+\frac{1}{C_2}\right) \end{bmatrix} \begin{bmatrix} I_1(S) \\ I_2(S) \end{bmatrix} = \begin{bmatrix} -\frac{V_0}{2}T_s-\frac{V_0}{S} \\ L_2I_{20}-\frac{L_2I'_{20}}{S} \end{bmatrix} \tag{1}$$

the initial conditions are

$$\begin{aligned} &i_1(0+)=I_0=-\frac{V_0T_s}{2L_1} \\ &V_{C_1}(0+)=V_0 \\ &i_2(0+)=I_{20} \\ &V_{C_2}(0+)=V_{20} \\ &\frac{d}{dt}i_2(0+)=I'_{20} \end{aligned} \tag{2}$$

Therefore, $I_1(s)$ and $I_2(s)$ are

$$I_1(s)=I_0\frac{S^3+\left(\frac{R_2}{L_1}+\frac{2}{T_s}\right)S^2+\left(\frac{2R_2}{T_sL_2}+N_0\right)S+\frac{2N_0}{T_s}}{[(S+\tau_1)^2+w_1^2]\,[(S+\tau_2)^2+w_2^2]}+I_{20}\frac{\sigma(S+1)}{[(S+\tau_1)^2+w_1^2]\,[(S+\tau_2)^2+w_2^2]} \tag{3.1}$$

$$I_2(s)=I_0\frac{n_0\left(S+\frac{2}{T_s}\right)}{[(S+\tau_1)^2+w_1^2]\,[(S+\tau_2)^2+w_2^2]}-I_{20}\frac{S^3+\left(\frac{R_1}{L_1}+\frac{I'_{20}}{I_{20}}\right)S^2+\left(\sigma+\frac{R_1I'_{20}}{L_1I_{20}}\right)S+\sigma\frac{I'_{20}}{I_{20}}}{[(S+\tau_1)^2+w_1^2]\,[(S+\tau_2)^2+w_2^2]} \tag{3.2}$$

where

$$2(\tau_1+\tau_2)=\frac{R_1}{L_1}+\frac{R_2}{L_2}$$

$$\tau_1^2+w_1^2+\tau_2^2+w_2^2+4\tau_1\tau_2=\frac{R_1R_2}{L_1L_2}+\frac{1}{L_2C_2}+\frac{1}{L_1C_1}+\frac{1}{L_2C_1}$$

$$2\tau_1w_2^2+2\tau_2w_1^2=\frac{R_1+R_2}{L_1L_2C_1}+\frac{R_2}{L_1L_2C_2}$$

$$(\tau_1^2+w_1^2)(\tau_2^2+w_2^2)=\frac{1}{L_1L_2C_1C_2}=G_0 \tag{4}$$

$$N_0=\frac{1}{L_2C_1}+\frac{1}{L_2C_2}$$

$$n_0=\frac{1}{L_2C_1}$$

$$\sigma=\frac{1}{L_1C_1}$$

$$G_2=\frac{1}{L_2C_2}+\frac{1}{L_1C_1}+\frac{1}{L_2C_1}$$

As shown in Eq.(3), the current $i_1(t)$ and $i_2(t)$ are damped by damping factor τ_1 and τ_2. Therefore the flyback is no longer symmetrical to flyback midpoint. So the conditions as shown in Eq.(5) for ringing to cease in lossless equivalent circuit is no longer applicable to lossy equivalent circuit where $\tau_1 \neq \tau_2$ in general and ringing cannot be made to cease at the end of the flyback.

$$R=\frac{w_2}{w_1}\doteqdot(2n+1)\frac{2(4n+1)T_f}{\pi^2 T_s}$$

$$(pq+p+1)^2=\left|\frac{\left(\frac{w_2}{w_1}\right)^2+1}{\frac{w_2}{w_1}}\right|pq \tag{5}$$

n : positive integer

$p=C_2/C_1 \quad q=L_2/L_1$

In Eq.(3), the second term is due to the ringing current. As far as the conditions for zero ringing are concerned, the second part can be neglected. In case of $\tau_1 \doteqdot \tau_2$, $i_2(t)$ becomes approximately

$$i_2(t)\doteqdot I_0\left\{e^{\tau_1 t}\,a\,\mathrm{Cos}\left(w_1 t-\frac{2}{w_1 T_s}\right)+e^{\tau_2 t}\,b\,\mathrm{Cos}\left(w_2 t-\frac{2}{w_2 T_s}\right)\right\} \tag{6.1}$$

$$v_2(t)=\frac{1}{C_2}\int i_2(t)\,dt$$

$$=\frac{I_0}{C_2}\left[\frac{a\,e^{\tau_1 t}}{\sqrt{w_1^2+\tau_1^2}}\,\mathrm{Sin}\left(w_1 t-\frac{2}{w_1 T_s}-\phi_1\right)+\frac{b\,e^{\tau_2 t}}{\sqrt{w_2^2+\tau_2^2}}\,\mathrm{Sin}\left(w_2 t-\frac{2}{w_2 T_s}-\phi_2\right)\right] \tag{6.2}$$

where $\phi_1=\mathrm{Tan}^{-1}\frac{\tau_1}{w_1}$

$\phi_2=\mathrm{Tan}^{-1}\frac{\tau_2}{w_2}$

The angular frequency(w_1,w_2) and amplitude(a,b) are not much different from those of lossless equivalent circuit, because w_1 and w_2 are generally larger than τ_1 and τ_2 in FBT Therefore if $\tau_1 \doteqdot \tau_2$ and the conditions of (5) are satisfied, the ringing becomes minimized. When τ_1 is different from τ_2 and the conditions(5) are satisfied simultaneously, there is an amplitude difference between i_{2w_1} and i_{2w_2} at $t=T_f$ which results in large ringing current during the scan time. It should be mentioned here that the amplitudes of current and voltage components are damped during the flyback time, so the first peak of the w_2 component of the primary voltage V_{c1} and that of the secondary voltage V_{c2} are larger than the second one. They are shown in Fig. 2 and Fig. 3 respectively.

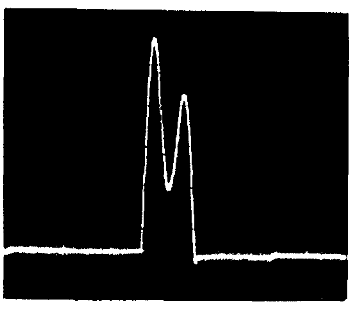


Fig. 2. Waveform of V_{c1} for 3rd harmonic tuning. (time scale ; 10 μs/div., voltage scale ; 10 V/div.)

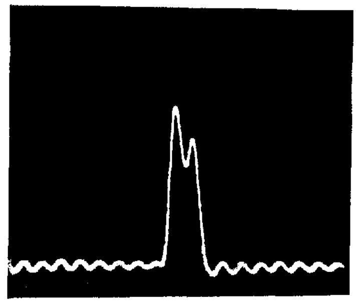


Fig. 3. Waveform of V_{c2} for 5th harmonic tuning. (scale ; 10 μs/div., 10V/div.)

3.2 Analysis of the Scan Time

From the Fig. 1-(b), the equation is

$$I_3(s)\left(S^2+\frac{R_2}{L_2}S+\frac{1}{L_2C_2}\right)=\frac{V_0}{L_2}+I_{2T_f}S-\frac{V_{2T_f}}{L_2} \tag{7}$$

where the initial conditions are

$$V_{c2}(0+)=V_{2T_f}$$
$$i_3(0+)=I_{2T_f} \tag{8}$$
$$\frac{d}{dt}i_3(0+)=I'_{2T_f}$$

Inverse Laplace Transform of Eq.(7) gives

$$i_3(t)=I_3 e^{\tau_3 t}\,\mathrm{Cos}(w_3 t+\phi_{30}) \tag{9.1}$$

And ringing voltage $v_3(t)$ is

$$v_3(t)=V_0+\frac{1}{C_2}\int i_3(t)\,dt$$

$$=V_0+\frac{I_3}{C_2}\frac{e^{-\tau_3 t}}{(w_3^2+\tau_3^2)^{\frac{1}{2}}}\,\mathrm{Sin}(w_3 t+\phi_{30}-\phi_4) \tag{9.2}$$

$$\tau_3=\frac{1}{2}\frac{R_2}{L_2},\quad w_3^2+\tau_3^2=\frac{1}{L_2C_2}$$

$$I_3=\left[I_{2T_f}^2+\left(\frac{1}{w_3}I'_{2T_f}\right)^2\right]^{\frac{1}{2}} \tag{10}$$

$$\phi_{30}=\mathrm{Tan}^{-1}\left(\frac{I'_{2T_f}}{I_{2T_f}w_3}\right),\quad \phi_4=\mathrm{Tan}^{-1}\frac{\tau_3}{w_3}$$

3.3 Conditions for Ringing To Cease

At $t=T_f$ the current $i_2(T_f)$ is divided into three components, $i_{2w1}(T_f)$, $i_{2w2}(T_f)$ and $i_{3w3}(T_f)$ Thus the resultant current must be re resented by vector addition of these components. Let $\mathbf{I}_3$ be the resultant current vector, then

$$\mathbf{I}_3 = \mathbf{I}_{2w1} + \mathbf{I}_{2w2} + \mathbf{I}_R \tag{11}$$

where $\mathbf{I}_{2w1}$, $\mathbf{I}_{2w2}$ and $\mathbf{I}_R$ are the current vectors of w_1, w_2 and ringing components respectively. If the relation between p and q is somewhat different from Eq.(5), the following formulas are valid.

$$\left.\begin{aligned} i_{2w1}(T_f) - i_{2w2}(T_f) &= I_{2T_f} \\ i'_{2w1}(T_f) - i'_{2w2}(T_f) &= I'_{2T_f} \end{aligned}\right\} \tag{12}$$

Let us suppose that $i_{2\bar{w}2}$ is a current component which satisfies the following equations.

$$\left.\begin{aligned} i_{2w1}(T_f) - i_{2\bar{w}2}(T_f) &= 0 \\ i'_{2w1}(T_f) - i'_{2\bar{w}2}(T_f) &= 0 \end{aligned}\right\} \tag{13}$$

Therefore $i_{2}\,w_2$ can be represented as folows

$$i_{2\bar{w}_2} = I_0\ e^{-\tau_1 t}\ a\ \mathrm{Cos}\left(Rw_1 t - \frac{2}{Rw_1 T_s}\right) \tag{14}$$

Evidently if i_{2w2} has the same value as the imagined $i_{2\bar{w}2}$, ringing during the scan time shall cease. Otherwise I_{2T_f} and I_{2T_f} are not equal to zero and ringing shall appear. Let the vector representation of $i_{2\bar{w}2}$ be $\mathbf{I}_{2w2}$, then

$$\mathbf{I}_{2\bar{w}_2}(T_f) = I_0\ a\ e^{-\tau_1 T_f}\ e^{j\left(Rw_1 T_f - \frac{2}{Rw_1 T_s}\right)} \tag{15}$$

$$\mathbf{I}_{2w_2}(T_f) = I_0\ b\ e^{-\tau_2 T_f}\ e^{j\left(w_2 T_f - \frac{2}{w_2 T_s}\right)} \tag{16}$$

If the Eq.(5) is satisfied, $\mathbf{I}_{2\bar{w}2}(T_f)$ and $\mathbf{I}_{2w2}(T_f)$ cancel each other depending on the sign of a and b. Since $a+b=0$, if $\tau_1=\tau_2$, $\mathbf{I}_{2\bar{w}2}$ and $\mathbf{I}_{2w2}$ shall cancel each other completely so that ringing during the scan time shall stop. If the Eq.(5) is not satisfied, there shall be phase difference between $\mathbf{I}_{2\bar{w}2}$ and $\mathbf{I}_{2w2}$ at $t=T_f$ which is given as

$$\phi_{\bar{w}_2} - \phi_{w_2} = (w_2 - Rw_1)\ T_f - \left(\frac{1}{w_2} - \frac{1}{Rw_1}\right)\frac{2}{T_s} \tag{17}$$

The magnitudes of $\mathbf{I}_3$ and $\mathbf{I}_R$ are determined by this phase angle and the difference between τ_1 and τ_2 On the other hand, the phase angle of $I_R(\phi_R)$ is obtained from Eq.(10) and ϕ_{30} is the initial phase angle at instant of scan. The ringing current is assumed to be continuous over T_s and T_f, thus roughly

$$\phi_R \doteqdot \phi_{30} + w_3 T_s + w_2 T_f \tag{18}$$

$$\text{If } \tau_2 > \tau_1,\ \text{then } |\mathbf{I}_{2\bar{w}_2}(T_f)| > |\mathbf{I}_{2w_2}(T_f)| \tag{19}$$

Under such circumstances as Eq.(19) is satisfied, $\mathbf{I}_3$ and $\mathbf{I}_R$ should lie on a straight line for minimum ringing, i.e.

$$\phi_R - \phi_3 = (2n+1)\pi$$

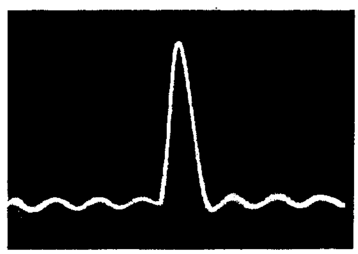
where ϕ_3 is the phase angle of $\mathbf{I}_3$.
At steady state $\phi_R=\phi_{30}$, therefore

$$w_3 Ts + w_2 T_f = (2n+1)\pi \tag{20}$$

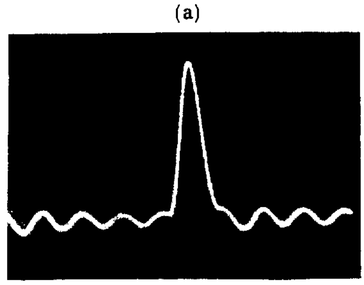
Eq.(20) is an additional condition for ringing to cease in lossy Flyback Transformer.

4. Experimental Results

If L_2 is increasing at fixed value of other para-



(a)



(b)

Fig. 4. V_{c2}—waveform for 3rd harmonic tuning
(a) when L_2 is too large and
(b) when L_2 is too small.
(scale ; 10μs/div., 10V/div.)

meters, the phase difference in Eq. (17) decreases, i.e.,
the vector I_{2w_2} rotates clockwise with respect to $I_{2\bar{w}_2}$.
On the other hand the vector I_{2w_2} rotates counterclockwise for decreasing L_2. Fig. 4 shows the dependence of ringing voltage on the value of L_2. When Eq.(5) and Eq.(20) are satisfied and τ_1 is slightly different from τ_2, the ringing voltage V_3 is nearly equal to V_0 at $t=0+$ but ringing does not cease.

CASE 1) $\tau_1<\tau_2$. I_3 lies in the second quadrant, thus

$$\frac{dV_3}{dt}\Big|_{t=0+}=\frac{1}{C_2}i_2(T_r)<0,\quad V_3\Big|_{t=0+}\doteqdot V_0$$

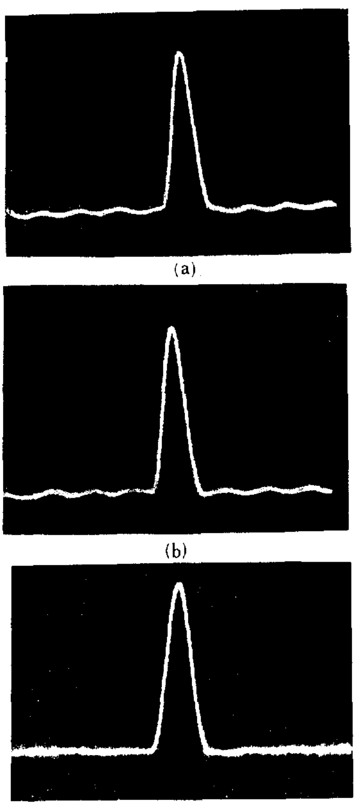
The ringing waveform for this case is shown in Fig. 5-(a).

CASE 2) $\tau_1>\tau_2$. I_3 lies in the fourth quadrant, thus

$$\frac{dV_3}{dt}\Big|_{t=0+}=\frac{1}{C_2}i_2(T_r)>0,\quad V_3\Big|_{t=0+}\doteqdot V_0$$

Fig.5-(b) shows the ringing waveform.

CASE 3) $\tau_1=\tau_2$ The ringing becomes zero. Fig. 5-(c) shows the ringing voltage of this case.



(a)
(b)
(c)

Fig. 5. Ringing waveform for 3rd harmonic tuning
(a) when $\tau_1<\tau_2$,
(b) when $\tau_1>\tau_2$ and
(c) when $\tau_1=\tau_2$.
(scale ; 10 μs/div., 10 V/div.)

The above pictures were taken in the following experimental circuit of Fig. 6. In Fig. 6 load is represented by parallel connection of equivalent capacitance(C_L) and resistance(R_L) of CRT.

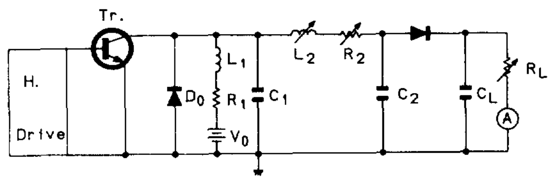


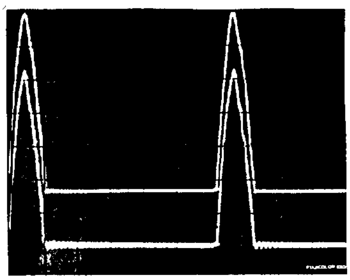
Fig. 6. Experimental circuit.
$L_1=920\,\mu$H　$L_2=$ Variable
$C_1=1.02$ nF　$C_2=3.97$ nF
Horizontal frequency : 15.75 kHz
$V_0=18$ V

5. Discussion.

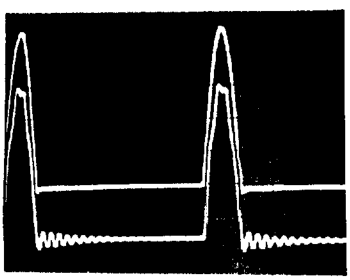
The result of theoretical analysis in lossy equivalent circuit shows a good agreement with experimental result. Of the six main parameters(R_1, R_2, L_1, L_2, C_1, C_2), L_1 is mainly determined by required deflection power. C_1 depends on retrace time and the required primary voltage. C_2 is largely a function of material, the structure of bobbin and the winding method. Only L_2 is left adjustable and must have a specified value to satisfy the zero ringing conditions. The harmonic tuning method in lossy circuit is very cumbersome so that the value of L_2 is mainly determined by trial-and-error method. And the variation of load condition and the nonlinear characteristic of magnetic material give rise to some deviations from the initial value of parameters, which makes it practically impossible to make the ringingless Flyback Transformer by using harmonic tuning method only.

Unharmonic-tuning method starts from the idea that the amplitude of ringing during the scan time may be suppressed within the permissible limit by decreasing the harmonic resonant energy and lowering the quality factor in R-L-C resonant circuit. We manufactured a prototype of ringingless FBT(section type) and almost zero ringing during the scan time was accomplished successfully. Fig.7-(a) shows V_{c2}-waveform of unharmonic-tuning FBT(prototype) which shows practically no ringing.

On the other hand V_{c2}-waveform of the 9th harmonic tuning FBT(Fig. 7-(b)) is a striking contrast to that of the unharmonic tuning FBT(Fig. 7-(a)) and shows about 10 percent of ringing ratio. The upper curve of Fig. 8, which is the frequency spectrum of the 13th harmonic tuning FBT, has two resonant frequencies(45kHz at first peak, 530kHz at second peak) so that the second resonant frequency must be the frequency which satisfies the harmonic tuning condition for minimum ringing.



(a)



(b)

Fig. 7. V_{c2}—waveform for
(a) unharmonic-tuning EBT (lower curve) and
(b) harmonic tuning FBT (lower curve).
* The upper curve is the primary voltage of FBT.(time scale : 10 μs/div. voltage scale : 200V/div. for upper curve,10V/div. for lower curve)

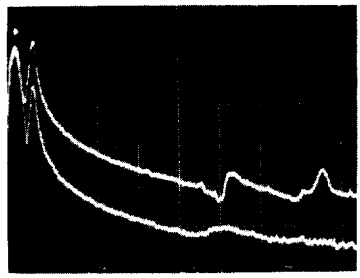


Fig. 8. Frequency spectrum for harmonic tuning FBT (upper curve) and for unharmonic-tuning FBT (lower curve). (scale : 100kHz /div., 10dBv/div.)
* Dot represents the reference (O kHz) point.

But the lower one does not have a noticeable second peak so that the second resonant frequency is not clear. This brings the effect of increase of number of the second resonant frequency to which the FBT must be tuned for minimum ringing on the practical basis. For this reason unharmonic-tuning FBT need not to be tuned to the unique correct harmonic tuning frequency but only need to be tuned to one of the above-mentioned second resonant frequencies-to the vicinity of the unique correct harmonic tunimg frequency for practically noringing.

By means of applying unharmonic-tuning method to FBT, the FBT designers can suppress the ringing within the permissible limit more easily compared with harmonic tuning case so that time and cost saving are attained at the FBT design stage.

6. Conclusions

From the theoretical analysis and the experimental result, following conclusions can be made;

1) In lossy circuit, the conditions for ringing to cease include the satisfaction of Eq.(5)

and Eq.(20) in addition to the condition of $\tau_1 = \tau_2$

2) By checking the waveform of ringing voltage, we can see if the value of L_2 is large or small.
3) Ringingless Flyback Transformer can be put into realization by combining the unharmonic and the harmonic tuning methods.
4) Analysis made by author can be applied to high voltage generator not only for color television receiver but for monitor display. But high voltage generating system for H.D.T.V. and H.D. monitor display in which the noise problem is more serious has to be further studied.

Appendix

1. Notations.

(1) C_e : Effective load capacitance.

(2) C_m : Mutual capacitance between the primary and the secondary windings of FBT.

(3) C_o : Tuning capacitance.

(4) C_p : Stray capacitance of the primary winding of FBT.

(5) C_s : Stray capacitance of the secondary winding of FBT.

(6) C_{sc} : S-correction capacitance.

(7) D_o : Damper diode.

(8) H. drive Horizontal drive stage.

(9) k : Coupling coefficient.

(10) L_2 : Leakage inductance between the primary and the secondary windings of FBT.

(11) L_o : Inductance of the primary winding of FBT.

(12) L_y : Inductance of horizontal coil of Deflection Yoke.

(13) R : Loss in inductor L.

(14) R_f : Fusable resistance.

(15) T_r : Horizontal output transistor.

(16) T_f : Retrace time.

(17) T_s : Trace time.

(18) V_o : B+ voltage.

(19) $i_{2w1}(T_f)$ Current of w_1-component.

(20) $i_{2w2}(T_f)$ Current of w_2-component.

(21) $i_{3w3}(T_f)$ Current of ringing component.

2. Derivation of Equivalent Circuit

There are three commonly used systems for generating the high voltage of television receivers

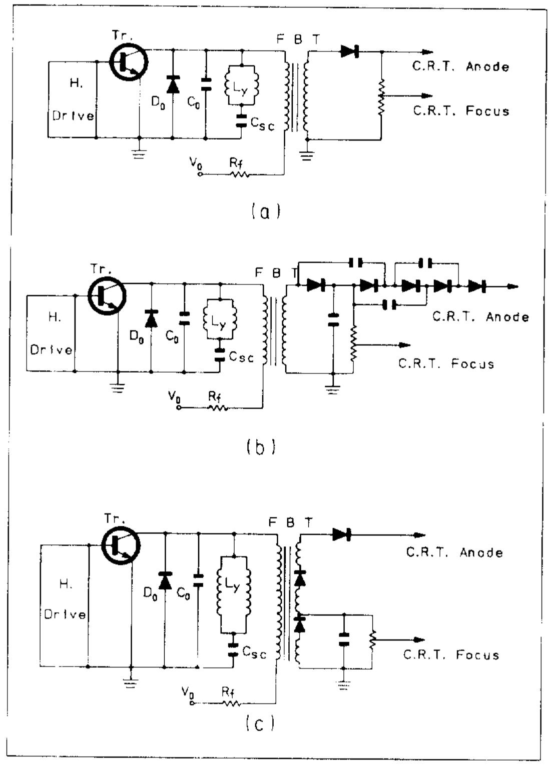


Fig. A-1. Basic horizontal system using
(a) singular type rectifier circuit,
(b) multipler type rectifier circuit and
(c) multistage singular rectifier circuit.

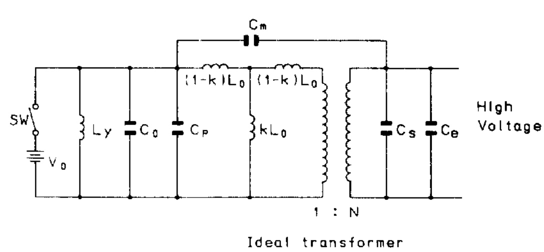


Fig. A-2. Horizontal system with T-equivalent circuit of FBT.

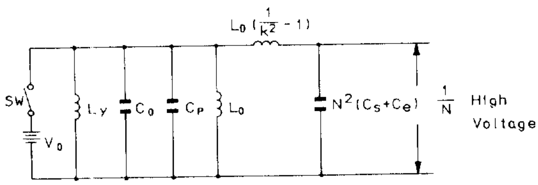


Fig. A-3. Simplified equivalent circuit.

as shown in the Fig. A-1.

As the influence of C_{sc} on the ringing of FBT is negligible, these systems can be replaced by equivalent circuit which is shown in Fig. A-2.

Neglect of mutual capacitance C_m in Fig. A-2 and some manipulation lead to simplified equivalent circuit of Fig. A-3.

References

1) Jee-sik Park, A Study on Low Ringing Flyback Transformer , Master thesis, Seoul National University, Feb. 1984.

2) Zuxun Ying and Zhensheng Zhu, "Ringing of Flyback Transformers", IEEE Trans. on Consumer Electronics, Vol. CE-28, No. 2, May 1982.

3) Ken-ichi Yoshida, Theoretical Analysis and Simulation of Flyback Transformer, National Technical Report, Vol. 20, No. 3, June 1974.

4) E.M. Cherry, "Third Harmonic Tuning of E.H.T. Transformers", IEE London Paper 3368E, March 1961.

5) Young-joong Kwon, "Analysis of Horizontal Deflection System in Television Receivers", Master thesis, K.A.I.S.T., 1977.

6) R.G. Woodhead, "The Influence on E.H.T. Regulation of the Harmonic Content in the Retrace Voltage of a TV Horizontal Output Stage", IEEE Trans. on Consumer Electronics, Feb. 1975.

7) L. R. Poel and J. C. Hanold, "Computer Aided Design of Horizontal Deflection Systems", IEEE Trans. on Broadcast and TV Receivers, Vol. BTR-16, No. 1, 1971.

8) Jeremy M.C. Tucker, "Computer Aided Design of Horizontal High-voltage Transformer for Solid State Deflection Circuit",IEEE Trans. on Broadcast and TV Receivers, Vol. B-TR 16, p. 112, 1970.

9) E. Corwin, " Computation of Electrical Parameters for Third Harmonic Tuned TV Horizontal Output Stages", IEEE Trans. on Broadcast and TV Receivers, Vol. BTR-14, No. 3, 1968.

10) T. Murakami, "Ringing in Horizontal Deflection and High Voltage Television Circuits", RCA Review 21, p. 17, March 1960.