Experiments of Hartley Oscillator

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INTRODUCTION

We had before examined that what percentage of $\mu\beta$ (the term μ is called the open-loop voltage gain, and the symbol β is used to denote the fractional gain of the feedback network) might become more than 1 to hold build-up of oscillators. As the result that we made, then, experiments on a CR phase-shift oscillator, practical oscillators are designed so that $\mu\beta > 1$ by about 5 percent in order to ensure oscillation.

And more we have investigated a Hartley oscillator for to arrive the general con-

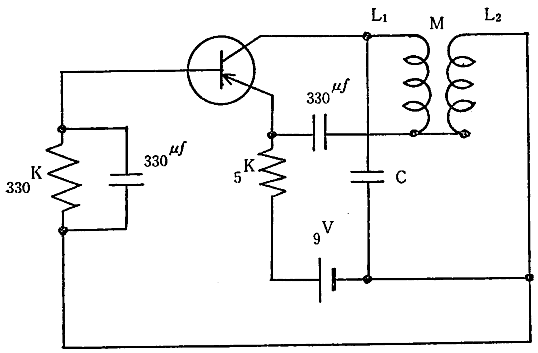

Fig. 1. A practical transistor Hartley oscillator circuit.

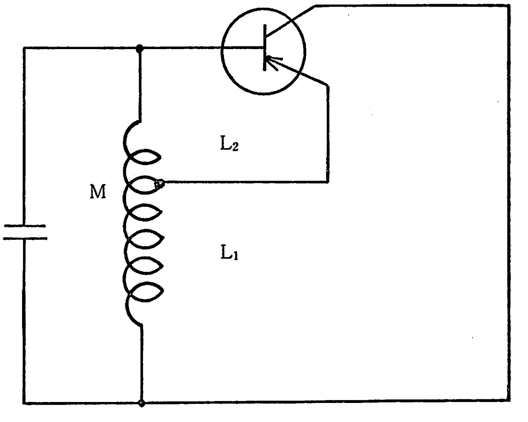

Fig. 2. The a-c equivalent of a Hartley oscillator.

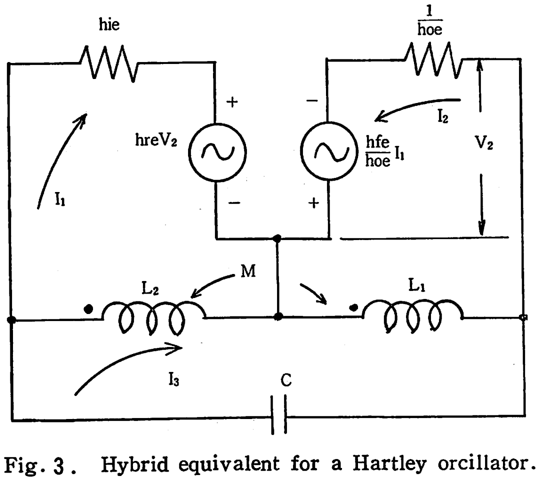

Fig. 3. Hybrid equivalent for a Hartley orcillator.

clusion. To keep the possibility of oscillation, the oscillator are designed $\mu\beta$ might become more than 1 by about 10 percent.

ANALYSIS AND EXPERIMENTS OF THE OSCILLATOR

A Hartley circuit having the practical biasing conditions shown in Eigure 1, its circuit without the biasing network is shown in Eigure 2. Its epuivalent circuit is redrawn in Figure 3, with the transistor hybrid circuit included. As seen, the circuit consists essentially of a grounded base amplifier having a tuned collector load. If we now consider driving this circuit with a source at a varying frequency, it is clear that we will obtain a maximum amplification only at the resonant frequency of the tuned circuit.

As a matter of fact, the amplification on either side of this frequency will drop off sharply if the circuit has a high Q. This is simply because the effective load impedance drops to a low value at frequencies different from resonance. Although the current gain of the oscillator is less than 1, there is a substantial voltage and power gain. We now write the three mesh equation to find the determinant for this Hartley oscillator. The equation for loop 1 becomes

$$I_1(h_{ie}+j\omega L_2)+I_2(-j\omega M)-I_3(j\omega L_2+j\omega M)+h_{re}V_2=0 \tag{1}$$

For loop 2,

$$-I_1(j\omega M)+I_2\left(\frac{1}{h_{oe}}+j\omega L_1\right)+I_3(j\omega L_1+j\omega M)-\frac{h_{fe}}{h_{oe}}I_1=0 \tag{2}$$

For loop 3,

$$-I_1(j\omega L_2+j\omega M)+I_2(j\omega L_1+j\omega M)+I_3\left(\frac{1}{j\omega C}+j\omega L_2+j\omega L_1+2j\omega M\right)=0 \tag{3}$$

It can be seen in Eigure 3 that V_2 is a function of I_2 and I_1, and the equations can be written

$$I_1\left(h_{ie}+j\omega L_2-\frac{h_{fe}h_{re}}{h_{oe}}\right)+I_2\left(\frac{h_{re}}{h_{oe}}-j\omega M\right)-I_3(j\omega L_2+j\omega M)=0 \tag{4}$$

$$-I_1\left(j\omega M+\frac{h_{fe}}{h_{oe}}\right)+I_2\left(\frac{1}{h_{oe}}+j\omega L_1\right)+I_3(j\omega L_1+j\omega M)=0 \tag{5}$$

$$-I_1(j\omega L_2+j\omega M)+I_2(j\omega L_1+j\omega M)+I_3\left(j\omega L_1+j\omega L_2+\frac{1}{j\omega C}+2j\omega M\right)=0 \tag{6}$$

Since the determinant of these equations is extremely complex, we Iook for any simplifications. At the resonant frequency the series reactance of the tank circuit is practically zero. With this approximation, the coefficient of I_3 in the third equation is zero. The resulting determinant of the coefficients is

$$\left(\frac{h_{re}}{h_{oe}}-j\omega M\right)(j\omega L_?+j\omega M)(j\omega L_1+j\omega M)+(-j\omega L_1-j\omega M)\left(j\omega M+\frac{h_{fe}}{h_{oe}}\right)(j\omega L_2+j\omega M)$$
$$-(-j\omega L_1-j\omega M)\left(\frac{1}{h_{oe}}+j\omega L_2\right)(-j\omega L_1-j\omega M)-(j\omega L_2+j\omega M)^2\left(h_{ie}+j\omega L_1-\frac{h_{re}h_{fe}}{h_{oe}}\right)=0 \tag{7}$$

The real part of the Equation (7) is found by expanding, collecting real parts, and the result is

$$\frac{\Delta h}{h_{oe}}(\omega L_1+\omega M)^2-\frac{h_{fe}}{h_{oe}}(\omega L_1+\omega M)(\omega L_2+\omega M)+\frac{1}{h_{oe}}(\omega L_2+\omega M)^2=0 \tag{8}$$

In this equation we solve for h_{fe}, using the fact that h_{re} is very much less than h_{fe} ; the final result is

$$h_{fe}\geqq\left(\frac{L_2+M}{L_1+M}\right)+\Delta h\left(\frac{L_1+M}{L_2+M}\right) \tag{9}$$

Since $1 \gg \Delta h$, the result is

$$h_{fe}\geqq\frac{L_2+M}{L_1+M} \tag{10}$$

Equation (10) gives the relation between transistor parameters and circuit inductance values to ensure the circuit function as an oscillator. This is referred as the condition for starting oscillations.

The frequency of oscillation as a function of circuit and transistor parameters can be found by equating the imaginary part of the Equation (7) to zero. Solving this relation for frequency, the result is

$$f=\frac{1}{2\pi\sqrt{C(L_1+L_2+2M)+\frac{h_{oe}}{h_{ie}}(L_1L_2-M^2)}} \tag{11}$$

Using the relationship $h_{ie} \gg h_{oe}$, the frequency is, to a good approximation,

$$f=\frac{1}{2\pi\sqrt{LC}} \tag{12}$$

where the total inductance of the coil is

$$L=L_1+L_2+2M \tag{13}$$

As the next step, we made the experiments on Toshiba transistor 2SA 499R, to find what percentage of increase $\mu\beta$ is necessary for ensure oscillation. In this case L_1 and M are variable and other component values are set in constant.

Set and measured values as follows;

$L_1=33.96\text{mH}$ $\quad L_2=98\text{mH}$

$M=15.43\text{mH}$ $\quad C=0.056\mu\text{f}$

Then $R_1=30\Omega$, and $R_2=21\Omega$ are equivalent resistance and $C_1\cong 200\text{P.F.}$, $C_2\cong 180\text{P.F.}$ are also distributed coil capacitance of L_1, and L_2, respectively. But since $\omega L_1 \gg R_1$, $\omega L_2 \gg R_2$, $C \gg C_1$, and $C \gg C_2$, we can neglect the effects of these resistances and capacitances.

The frequency of oscillation is about 1700 HZ.

$$\frac{L_2+M}{L_1+M}=2.3$$

$h_{fe}=2.5$, this experimental value is found when I_B is nearly equal to 20 μA.

Consequently, taking the Equation (10) which is a condition for starting oscillations, practical Hartley oscillators are designed so that $\mu\beta > 1$ by about 10 percent in order to ensure oscillation even with minor changes in circuit or device parameters.

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REFERENCES

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