TWENTIETH WEEK.
FUNDAMENTAL TRANSMITTING
CIRCUITS.

G.B.Todd, RM1c.

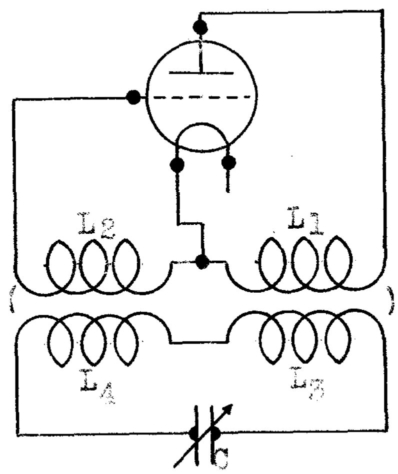
3.7

QUESTION #1. & #8. Of what does a tube circuit consist, when it is so arranged that it will generate oscillations?

ANSWER #1. The fundamental requirements of a tube circuit that will generate oscillations are: An oscillatory circuit containing inductance and capacity through which the grid and plate circuits of the tube are coupled either inductively, capacitively or directly in such a manner that the phase relationship between the two circuits will be the same. The coefficient of coupling between the grid and plate circuits is more or less critical.

QUESTION #2. Draw a fundamental Meissner circuit omitting batteries. What does the circuit consist of?

ANSWER #2.



The Meissner Circuit.

The oscillatory circuit consists of the coils L3 and L4 and the condenser C. In transmission the condenser C would be replaced by the antenna. The coil L1 is included in the plate circuit of the tube and is coupled to the coil L3 while the coil L2 is included in the grid circuit of the tube and is coupled to L4. Feeble oscillations occuring in the oscillatory circuit will induce an alternating voltage in coil L2 which will act on the grid, producing variations in the plate current flowing thru L1 and these will produce an alternating voltage in the coil L3 which with the proper sign and sufficient strength of coupling, will reinforce the original oscillations causing them to increase in amplitude. The increased oscillations will induce a still greater voltage in the coil L2 and correspondingly greater variations in the current thru L1, leading to a further increase in the oscillating current. This building-up process continues until the vacuum tube cannot supply enough power to the oscillatory circuit to increase further the amplitude of the oscillations and an alternating current of constant amplitude will flow in the circuit having a frequency very nearly that of the natural period of the oscillatory circuit.

QUESTION #3. Explain how oscillations are generated and maintained in the Meissner circuit.

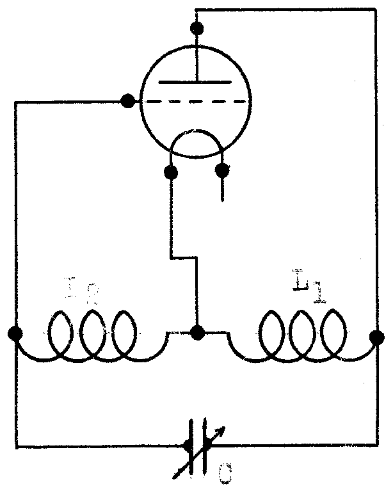
ANSWER #3. If a difference of potential be maintained between the plate and filament of the tube, with the plate positive in respect to the filament, a current will flow in the plate circuit and through coil L1. A magnetic field is thus set up about coil L1 and this field cuts the turns of L3 inducing an EMF in the tuned circuit L3 L4 and C. L2 is cut by the lines of force from L4 and the arrangement of coil winding and connections is such that the resulting Emf generated in L2 and applied to the grid of the tube is in the same phase relation as the current flow in L1 The initial current flow in the plate circuit thus causes the grid of the tube to become more positive which in turn causes an increase in plate current, strengthening the fields and increasing the positive potential on the grid. This action continues until the plate current becomes maximum and this value will depend upon the electron emission and the potential applied between the plate and the grid of the tube. At this point the first oscillation has reached its maximum amplitude in one direction and the plate supply is supplying enough energy to the circuit to compensate for that dissipated in radiation, in overcoming resistance and the other losses taking place in the circuit. When the plate current reaches its maximum value, there is no further increase to maintain the field about L1 and the field collapses inducing an emf in the opposite direction. A consequent reversal of potential is applied to the grid of the tube and thus reduces plate current until the minimum value of plate current is flowing at which point no further decrease can be made to maintain the negative potential on the grid and it returns to its original potential which value depends upon the value of the grid leak or the potential of the grid bias battery. The plate now takes another rush of current from the plate power supply. The grid is alternately thus swung negative and positive and plate current increases when the grid is positive and decreases when it is negative, maintaining oscillations of a constant amplitude if the plate supply is of constant potential and at a frequency dependent upon the LC value of the tuned oscillatory circuit. The plate supply furnishes just enough power to supply that dissipated by all of the losses in the circuit.

QUESTION #4. Draw the fundamental Hartley circuit. How does it differ from the Meissner circuit?

ANSWER #4.

(see next sheet)

ANSWER #4. Continued.

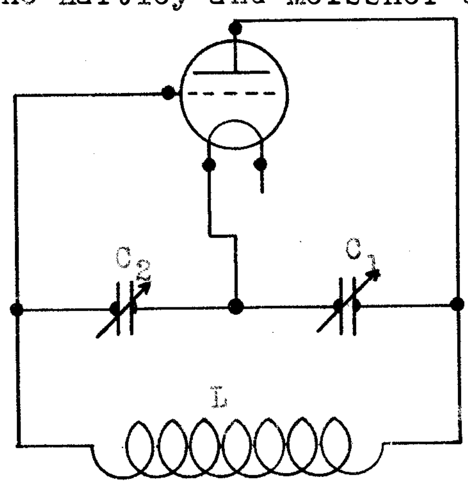


The Hartley Circuit.

The Hartley circuit differs from The Meissner circuit in that L1 and L2 are directly (inductive) coupled instead of indirectly coupled. L1 and L2 are shunted by capacity C and together form the oscillatory circuit and determine the frequency of oscillations. The magnetic field of the two inductances cut both coils and a transfer of energy takes place from plate to grid circuits and, if the phase relationship between the circuits is the same, oscillations will occur. Ordinarily, coil L1 and L2 is a single coil with an intermediate connection to the filament.

QUESTION #5. Draw the fundamental Colpitts circuit. How does this differ from the Hartley and Meissner circuits?

ANSWER #5.



The Colpitts Circuit.

The common return of grid and plate to filament is taken off at an intermediate point between capacities instead of an intermediate point between L1 and L2 as in the Hartley and Meissner circuits. The oscilla tory current flow occurs through the inductances and capacities both, and the voltage distribution across the inductance and capacitance is about the same insofar as the highest RF voltage is present

ANSWER #5. Continued.

at the extremities of the coil and the voltage node occurs at the common return to filament. The center tap between condensers is likewise at a voltage nodal point. The proper combination of series inductance and capacitance renders the reactance of the circuit less than would be the case if either the inductance or capacity were deleted from the circuit. This is because capacitive reactance and inductive reactance have opposite characteristics and carry unlike algebraic signs and the total reactance is the algebraic sum of the two. The grid circuit in the Hartley is thus through the inductance L, condenser C1 back to filament, while the plate circuit is through the inductance L thru C2 and back to filament. Inductance L being common to both circuits, a transfer of energy takes place between circuits and the phase relationship of both circuits must be the same. The Colpitts circuit both theoretically and practically is generally conceded to be as good or better than any other oscillating circuit. It is more stable because a large capacity is always in shunt with the parasitic capacity which exists between plate and grid, between grid and filament and between plate and filament, within the tube.

QUESTION #6. What is meant by half-wave rectified transmitting circuit? How obtained?

ANSWER #6. Plate current, in any vacuum tube, will flow, only when a positive potential is applied to the plate, in respect to the filament, because, when this condition exists, electrons, leaving the filament, will be attracted to the plate, and will flow between the filament and plate, whereas, when the plate is negative, in relation to the filament, the electrons will be repelled and prevented from reaching the plate; thus no plate current will flow. If an alternating voltage is now impressed between the plate and filament of the tube, the tube will act as a rectifier at the same time also functioning as an oscillator. Oscillations thus occur only during the time when the plate is positive, or "on the positive half of the cycle." Oscillations are thus intermittent and, as the voltage is continually varying sinusoidally, the resulting oscillations are not of constant amplitude. The tone frequency will be the same as the frequency of the impressed alternating current insofar as oscillations and one wave train occurs once each cycle.

QUESTION #7. How are two tubes hooked in a transmitting circuit to obtain full-wave rectification, using AC on the filaments and plates?

ANSWER #7. The filaments of the two tubes are heated by a filament transformer secondary. Each of these two tubes

ANSWER #7. Continued.

is used as an oscillator or amplifier and automatically rectifies its own plate current by allowing current to flow only during the positive half of the cycle as previously explained. The plate transformer, which supplies high voltage AC to the plate circuits, must have its secondary so wound that it supplies double the voltage desired on each tube and the extremities of the secondary connect to the plate circuit of each tube through a radio frequency choke in such a manner that, when one end of the winding is positive, it will supply potential for one tube, and, when the opposite end is positive, it will supply potential for the other tube. The transformer secondary is center-tapped and this center-tap serves as the negative plate supply regardless of which tube is in operation. Thus one tube operates while the other tube idles and each tube is in operation during one half of the cycle. The result is continuous oscillations which, however have a constantly varying amplitude because of the sinusoidal voltage variation. The resultant tone will be twice the frequency of the applied AC as each tube functions during one cycle. This circuit requires the use of matched tubes having identical characteristics because the oscillatory current from each tube is usually fed through a common LC circuit and the tone will be smooth and stable only when the tube characteristics are approximately the same.

QUESTION #9. What conditions exist in order to stop oscillations from being generated from a vacuum tube?

ANSWER #9. The tube will stop oscillating if the coupling between the grid and plate circuits is reduced to a point where the feed-back is insufficient to maintain oscillations. If the plate or filament circuits are broken the tube stops oscillating. If the resistance of the LC circuit is so high that oscillations that oscillations are damped out before they can make a complete reversal, the circuit stops oscillating. If the load placed upon the circuit is greater than the plate supply can furnish while still supply ing sufficient energy to compensate for RF dissipation losses, the circuit will stop oscillating. If the grid bias becomes so negative as to reduce the plate current to a point where is is unable to supply the losses the tube will stop oscillating. If the grid becomes free, the plate current will be reduced to almost zero quicker than the reduction could be accomplished with a switch. This latter fact is taken advantage of to prevent arcing at the key when breaking the plate supply when keying is accomplished in the so called center tap of the filament transformer, because the high negative potential impressed upon the grid of the tube blocks the plate supply before arcing has time to occur. If the plate supply becomes negative with respect to the filament the tube will stop oscillating. If the ratio of capacity to inductance becomes too great the tub the will stop oscillating.

QUESTION #10. How are adjustments made in vacuum tube transmitting circuits to obtain maximum output?

ANSWER #10. The grid coupling or the amount of energy transferred from the plate circuit to the grid circuit determines the grid excitation. The best operating conditions is with the grid excitation reduced to a point just a little above where the tube ceases to oscillate. At this point maximum radiation or load can be obtained with minimum plate current and thus the efficiency of the tube is increased. If the critical point is approached too closely the tube will be erratic or unstable in operation so grid excitation should be slightly greater than is necessary to maintain oscillations. In the Meissner circuit, grid excitation can be varied by a variation in coupling between the grid circuit and the LC circuit. In the Hartley or Colpitts circuits, the grid excitation is varied by varying the voltage nodal point either way from the center tap of the inductance. In the Hartley circuit moving the center tap toward the grid end reduces excitation because the grid portion of the inductance is incorporating less turns than before and the voltage drop between the grid and filament will be less than before. In the Colpitts circuit, the same results may be obtained by varying the rescpective values of the center-tapped condensers. If the grid circuit contains the lower value of capacity, the excitation is lessened. In the Colpitts circuit, the grid condenser is the one connected to the plate end of the inductance coil.

QUESTION #11. What disadvantages are there in using coupled tuned circuits? In using conductive or direct capacitive coupling?

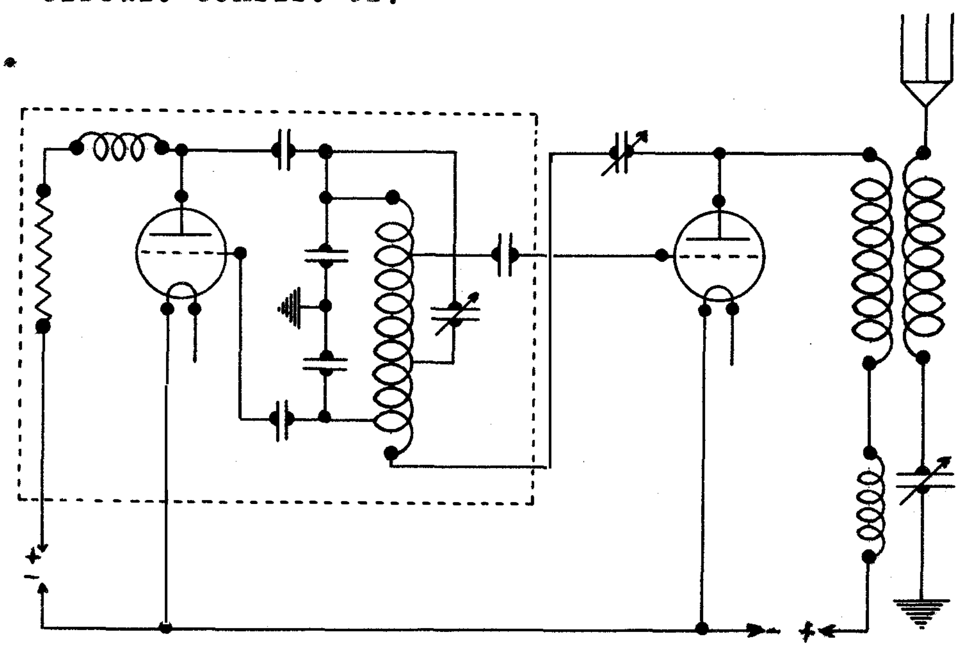
ANSWER #11. When the resistance of both circuits is extremely low, coupled tuned circuits are not satisfactory, because, at this condition, a large transfer of energy will take place even with very loose coupling. A marked reduction in transfer occurs when the coupling is loosened to a critical point and thus the adjustment of coupling is very critical often resulting in erratic operation. When large energy transfer is made from one circuit to the other using coupled tuned circuits and the resistance of each is low, a large retransfer of energy takes place to the oscillation generating circuit causing two frequencies to be generated. In the case of master-oscillator power-amplifier circuits, where the coupling between the master-oscillator and the power-amplifier is inductive, the stability of the oscillator is easily disturbed and it is difficult to prevent the amplifier from oscillating. Where the resistance of one of the circuits is fairly high, inductive coupling is desirable. Antenna circuits have comparatively high resistance because of the radiation resistance and it is advisable to use inductive coupling to insure the

ANSWER #11. Continued.

emission of a sharp pure wave of low decrement. Direct coupling tends to broaden the emitted wave and as actual contact exists between the two circuits harmonic frequencies are readily radiated. Direct capacitive coupling is little used in antenna circuits because the low reactance of condensers at radio frequency allows the harmonic frequencies to pass almost as readily as when direct contact is made. Capacitive coupling is used mostly for coupling MOPA circuits because the tendency of the power amplifier to oscillate at the frequency of the oscillator is greatly reduced and little neutralization is necessary. Of ten when the master oscillator is well shielded, capacitive coupling can be used and no neutralization is necessary to prevent amplifier oscillations.

QUESTION #12. Draw a fundamental master-oscillator power-amplifier (MOPA) transmitting circuit. What does the circuit consist of?

ANSWER #12.



Fundamental Master-Oscillator Power-Amplifier Circuit using Colpitts Oscillator.

Any oscillator circuit may be used, but in this case the Colpitts oscillator circuit has been used. The circuit consists of the oscillator circuit with its filament and plate supply. Both filament and plate supply may be common to both the oscillator and amplifier although usually in practice less voltage is used on the oscillator, than on the amplifier. Such is the case in this diagram and a series reactance has been used to lower the voltage. Assuming the normal oscillator plate current to be 100 MA and the voltage on the plate to be 750, the value of the resistance is,

ANSWER #12. Continued.

by Ohm's Law, 12,500 Ohms and it must be of sufficient dimensions to safely dissipate 125 watts of energy continuously. The amplifier consists of a plate tank circuit which is tuned in this case to the same frequency as the oscillator. In the case of a crystal controlled oscillator sometimes the amplifier is tuned to one of the crystal's harmonic frequencies. The grid of the amplifier is untuned but is driven by the oscillations from the amplifier by means of capacitive coupling of the grid of the amplifier with the plate circuit of the oscillator. A negative grid bias is usually used and keying of the amplifier can be easily and stably accomplished in this circuit. Keying in the amplifier circuit (grid) does not give rise to unstable operating conditions as is the case when keying is done in an oscillator grid circuit. In the power amplifier, the relationship between the grid and plate current is perfectly lined whereas an oscillator grid current bears no such relationship to the plate current. When a harmonic frequency of a crystal controlled transmitter is being used to drive the power amplifier, the amplifier grid always is maintained at a high negative potential as this tends to increase the amplification of any harmonic frequency used. Neutralization is accomplished in this case by feeding a portion of the energy from the grid end of the oscillator to the plate of the amplifier through a small series condenser which serves to exactly compensate in value for that applied from the oscillator plate to the amplifier grid circuit and also prevents a positive potential from the amplifier plate circuit from reaching the oscillator grid. The neutralization feed-back is from the opposite end of the coil from that of the feed which swings the amplifier grid and consequently is 180° different in phase and as its value is adjusted to be exactly equal to the feed which swings the amplifier grid, complete cancellation takes place. The amplifier grid however is much easier to swing than would be the amplifier plate circuit so the amplifier is controlled by the feed from the oscillator plate. Suitable blocking, bridging and controlling condensers are included in the circuit as well as suitable RFCs, the purpose of which is either obvious or has been previously explained. The plate tank circuit of the amplifier is inductively coupled to the antenna system. The degree of feed from the oscillator to the amplifier grid is readily adjusted by means of a clip which can be set at any point between the center of the indectance and the plate end of the oscillator coil. The voltage node exists at the center of the oscillator coil and the high voltage at the extremities of the coil so the transfer of energy will be zero when the clip is in the center

ANSWER #12. Continued.

and maximum when at the end. The smallest load on the oscillator possible should be used to drive the grid of the amplifier for the less the load of the oscillator circuit the more isolated it will be and oscillations will be more stable. The oscillator should be shielded and the shield grounded but in any case there should never be any coupling between the oscillator and amplifier coils for if such is the case neutralization will be nearly impossible.

QUESTION #13. What is the advantage of the MOPA over an oscillator connected directly to an antenna system?

ANSWER #13. A heavy load must be drawn from the oscillator when the oscillator is directly connected to the antenna system, and consequently the oscillator is less stable in frequency. Re-transfer of energy from the antenna circuit to the oscillator will cause additional unstability and if the antenna swings, the oscillator frequency will swing. Harmonics from the oscillator are readily radiated. In the MOPA circuit, the isolated oscillator runs steadily and with constant frequency because little load is placed upon it. The oscillator ordinarily is not keyed and the frequency swing caused by keying is eliminated. Harmonic frequencies from the oscillator are not amplified unless the amplifier plate tank is tuned to the harmonic frequency. MOPA circuits are especially valuable where the antenna may swing or at any time when the frequency must be maintained constant.

QUESTION #14. Explain the operation of the MOPA circuit.

ANSWER #14. An explanation of the operation of the master-oscillator power-amplifier circuit was given under the answer to Question #12. The oscillator oscillates at the frequency of its LC circuit or at the frequency of the crystal driver. The output of the oscillator is fed to the grid circuit of the amplifier tube either inductively or, preferably, capacitively, and, as the grid of the amplifier is swung by the radio frequency oscillations of the oscillator, it will amplify the characteristic wave form and frequency of the oscillator in the plate tank of the amplifier but at a much higher amplitude depending upon the amplification constant of the amplifier tube. The amplifier circuit should never oscillate and preferably should not be in a regenerative condition.