Double @-@ tuned amplifier

A double @-@ tuned amplifier is a tuned amplifier with transformer coupling between the amplifier stages in which the inductances of both the primary and secondary windings are tuned separately with a capacitor across each . The scheme results in a wider bandwidth and steeper skirts than a single tuned circuit would achieve .

There is a critical value of transformer coupling coefficient at which the frequency response of the amplifier is maximally flat in the passband and the gain is maximum at the resonant frequency . Designs frequently use a coupling greater than this (over @-@ coupling) in order to achieve an even wider bandwidth at the expense of a small loss of gain in the centre of the passband .

Cascading multiple stages of double @-@ tuned amplifiers results in a reduction of the bandwidth of the overall amplifier . Two stages of double @-@ tuned amplifier have 80 % of the bandwidth of a single stage . An alternative to double tuning that avoids this loss of bandwidth is staggered tuning . Stagger @-@ tuned amplifiers can be designed to a prescribed bandwidth that is greater than the bandwidth of any single stage . However , staggered tuning requires more stages and has lower gain than double tuning .

Typical circuit

The circuit shown consists of two stages of amplifier in common emitter topology . The bias resistors all serve their usual functions . The input of the first stage is coupled in the conventional way with a series capacitor to avoid affecting the bias . However , the collector load consists of a transformer which serves as the inter @-@ stage coupling instead of capacitors . The windings of the transformer have inductance . Capacitors placed across the transformer windings form resonant circuits which provide the tuning of the amplifier .

A further detail that may be seen in this kind of amplifier is the presence of taps on the transformer windings . These are used for the input and output connections of the transformer rather than the top of the windings . This is done for impedance matching purposes ; bipolar junction transistor amplifiers (the kind shown in the circuit) have a quite high output impedance and a quite low input impedance . This problem can be avoided by using MOSFETs which have a very high input impedance .

The capacitors connected between the bottom of the transformer secondary windings and ground do not form part of the tuning . Rather , their purpose is to decouple the transistor bias resistors from the AC circuit .

Properties

Double tuning , as compared to single tuning , has the effect of widening the bandwidth of the amplifier and steepening the skirt of the response . Tuning both sides of the transformer forms a pair of coupled resonators which is the source of the increased bandwidth . The gain of the amplifier is a function of the coupling coefficient , k , which is related to the mutual inductance , M , and the primary and secondary winding inductances , Lp and Ls respectively , by

<formula>

There is a critical value of coupling at which the gain of the amplifier is a maximum at resonance . Below this critical value , there is a single peak in the frequency response with the amplitude peaking at resonance and the peak decreasing as k decreases . Such a response is said to be undercoupled , At values of k above critical coupling the response starts to split into two peaks . These peaks become narrower and further apart as k increases and the gap between them (centred on the resonant frequency) becomes progressively deeper . Such a response is said to be overcoupled .

A critically coupled amplifier has a response that is maximally flat . This response can also be achieved without transformers with two stages of a stagger @-@ tuned amplifier . Unlike staggered tuning , double tuning usually tunes both resonators to the same resonant frequency . However , a

designer might choose to design an overcoupled amplifier in order to achieve a wider bandwidth at the expense of a small dip (typically 3 dB) in the centre of the frequency response .
Like synchronous tuning , adding more stages of double @-@ tuned amplifiers has the effect of reducing the bandwidth . The 3 dB bandwidth of n identical stages , as a fraction of the bandwidth of a single stage , is given approximately by ,
<formula>
This expression applies only to small fractional bandwidths .

= = Analysis = =

The circuit can be represented in a more generic way by replacing the amplifiers with a generalised transconductance amplifier as shown .
where (omitting the stage number suffixes) ,
Go is the output conductance of the amplifiers
Gi is the input conductance of the amplifiers .
Typically , a design will make the resonant frequencies and Qs on the primary and secondary sides identical , such that ,
<formula>
and ,
<formula>
where ?0 is the resonant frequency expressed in units of angular frequency and the subscripts p and s refer respectively to components on the primary and secondary side of the transformer .

= = = Stage gain = = =

With the above assumptions , the voltage gain , A of one stage of the amplifier can be expressed as

<formula>
where
<formula> is the imaginary unit ,
<formula>
is the maximum gain deliverable by the stage , and
<formula>
is the frequency expressed as the fractional frequency deviation from the resonant frequency .

= = = Peak frequency = = =

With less than critical coupling , there is one peak in the response occurring at resonance . Above critical coupling , there are two peaks at frequencies given by
<formula>
where ?L and ?H are respectively the low and high frequencies of the peaks expressed as fractional deviation .
With critical coupling or above , the peaks reach the maximum gain available from the amplifier .

= = = Critical coupling = = =

Critical coupling occurs when the two peaks just coincide . That is , when
<formula>
or
<formula>