WHAT IS BIAS?

Biasing in electronics is a method that establishes predetermined voltages or currents, at various points of an electronic circuit, for the purpose of establishing proper operating conditions in electronic components.

Bias is often misunderstood. Bias can mean different things to different people, unless circuit theory is used to understand Bias.
Bias has been around since the first circuits were designed, so lets explore this important adjustment (when available).
Bias is often associated with a Circuit at rest, meaning that a Circuit once powered-up, will reach a balanced "quiescent" state, where DC voltages and DC currents reach a fixed set of idle values.
Bias can also be non-adjustable, this is where most of the confusion lies. Trying to undestand a particular amplifier and whether it offers or does not offer Bias adjustments?

When it relates to Tube Power Amps, Bias is always present. Some amps offer adjustable bias control as a way to be able to change the amount of standing DC current through a particular Power Tube.
There are generally two kinds of Biasing arrangements; Fixed Bias and Cathode Bias.
The names used to describe Bias create lots of confusion as the words used aren't generally conveying the actual curcuit behavior.

CATHODE BIAS (OR SELF BIAS) RARELY USER ADJUSTABLE:

Cathode Bias is almost exclusively non-adjustable (there are exceptions), it relies on a concept called self-feedback.
A Cathode resistor is used to establish an opposition to the current flow through the Power Tube.
Cathode Bias can be implemented individually on each Power Tube, or it can be accomplished in pairs or even odd numbers of Power Tubes.
We install a Power Resistor in the Cathode of the Power Tube, to ground. This allows Cathode Current to flow through the resistor.and this causes a Bias Voltage to be produced, warming up the resistor.
This flow of current through the resistor causes a voltage to be produced. Resistors are voltage control devices so according to their value, the higher the resistance the higher the voltage drop across it.
When we cause Cathode Current to flows through a Bias Resistor, we are draining the energy out of the tube itself to ground, causing a flow of electrons and heat.

So if you picture it, a Power Tube stands on top of a Cathode Power Resistor.
Power Tubes are 'stood-up' on a Cathode Resistor then through self-feedback, the Voltage increase and what is produced is reflected back into the Power tube itself and stops the tube from running away.
The bias current uses the Cathode resistor to generate a Bias Voltage and then hold it, this in the simplest terms is Bias, the ability to put a Tube under Controlled Conduction and do work.
Just look for Rk (Resistor Cathode), they will show a value typically for 2 Tubes, if you want you can connect 4 tubes tom a single Cathode Resistor, but preferably they need to be matched quads.
Cathode Bias is far more sensitive to variations in the tubes. Fixed Bias allows adjustments that can often, but not always allow a tube to operate. Sometimes tubes are just to far away to work on pairs.

The older the Tube, the more current it draws, pulling down the Power Supply voltage a bit.
Failure mode 1 = Open Circuit, much better, safer. Failure Mode 2 = Short Circuit, often bad news for the amp or a component in the amp.

Bias is used to "lock-in" a DC tube current level, to remain steady, not change, hence the DC Voltages on the tubes don't change.
Proper Bias means putting the tubes to operate at or close to what they are published to be capable of. Then tubes slowly age, standing currents change.

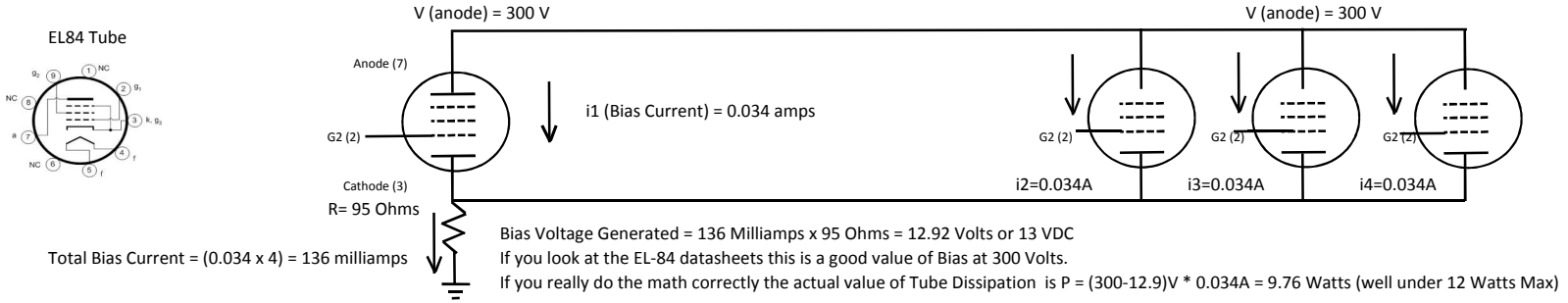
In a Cathode Biased amp Power Tubes will eventually wear out, and the Cathode Resistor can often become overheated.
Cathode Bias is a passive circuit, meaning that there is no separate Voltage generation or supply, the Cathode Bias voltage is produced by the flow of current through the Bias resistor.
In contrast, Fixed Bias has a dedicated Power Supply circuit that rectifies AC into a Negative -DC Voltage, we will discuss this is the Fixed Bias section below.

CASE STUDY: DYNACO ST-35 STEREO AMPLIFIER 17.5 WATTS PER CHANNEL.

EL-84 Cathode Bias Example (as in the Dynaco ST-35 and many similar amps of that era):
Cathode Bias in the ST-35 relies on a fixed common resistor to the 4x Cathodes of the 4x Power tubes to set the Bias level. This 95 Ohm Bias Resistor is rated at 5 Watts.
In most Cathode biased amps this value is determined looking at the databooks and fetching the Bias Resistor value Rk and designing the tube with the suggested voltaged in the manual.

There are other very creative implementations of Cathode Bias, like the Harman Kardon A500, and you can read and see this from the schematic in the other section of my website.

ST-35 POWER OUTPUT TUBES CONNECTED TO THE BIAS RESISTOR. THIS IS NON ADJUSTABLE. AND USES MATCHED POWER TUBES FOR BEST SOUND.



In the above example, I have 287.1 Volts on the Anode (Plate) of the ST-35 Output Tubes and all 4 Cathodes tied together through a 95 Ohm Bias Resistor.
The net effect of the sum of the four tubes is to allow a grand total of 136 milliamps of current through Bias Resistor = R, that generates a Bias Voltage of 12.92 Volts across the Cathode Bias Resistor.
This Cathode Bias is like a permanent "current brake" and "parks the EL84 Tubes" at their quiescent operating point on the Dynaoc ST-35, it is textbook Cathode Bias.
Many European Tube amps favor this method.
This method works best with matched power tubes as there is no Bias adjustment to even out differences.
In some cases of Cathode Bias, we have an adjustable Cathode Resistance, and this is rarely seen in Classic Audio designs for some specific reasons I will explain later.

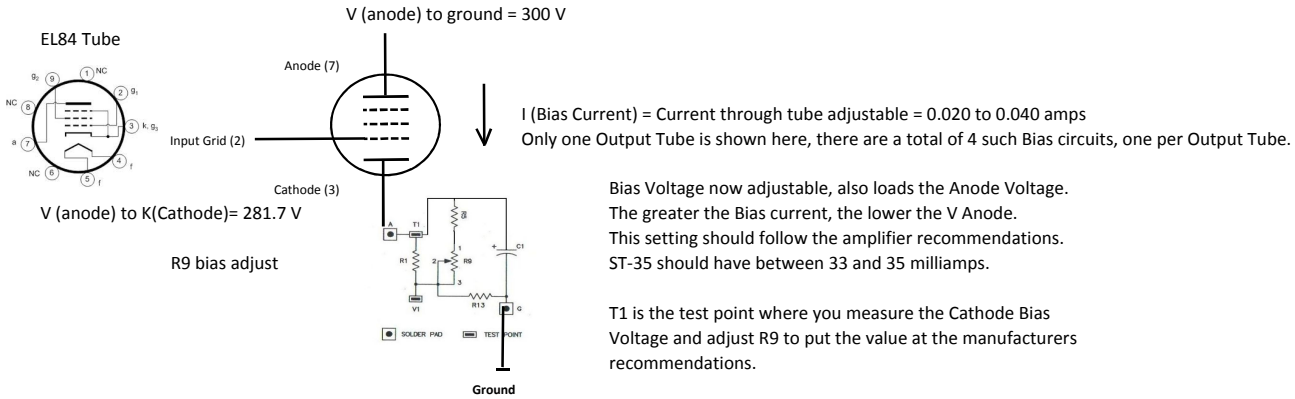
Adjustable St-35 Cathode Bias (Special Bias Board from DynakitParts):
The Dynaco ST-35 unlike to Dynaco ST-70 does not have any Bias Control adjustments and is a Cathode Bias design, unlike the Dynaco ST-70 that implements a fixed-bias arrangement.

The ST-35 is what we know as Cathode Bias, it uses a Resistance in the Cathode Circuit to develop a Bias Voltage.single 95 Ohm, 5 Watt resistor.

The factory design uses a single 95 Ohm Power Resistor that is tied to ground.

The other side of the Cathode Bias resistor provides the Bias Voltage and is connected to all fous of the output EL-84 Tubes Cathodes.

This DC voltage is produced when current from all 4 Power Tubes flows simultaneously through the Bias Resistor and creates a DC Bias Voltage.
The DC Cathode Bias board provides individual Bias adjustment for each power tubes in the form of a separate resistor network with a small multi-turn potentiometer.
You will measure a DC voltage Point A that is the result of the current that flows through R1, R5, R9 and R13, with R9 being adjustable.
The values of this Bias Control Circuit were chosen so that 0.344 Volts DC at Point A is equivalent to 34.4 milliamps DC through the Tube.



The reason why we don't see adjustable Cathode Bias is the potential damage that setting the controls can do to the amp. The same can be said about
Fixed Bias adjust, damage is also possible there as well. So knowing how to properly adjust Bias and knowing when you need to buy matched tubes is key.

Adjustable Cathode Bias is not common. To properly set this type of Bias, you also should measure simultaneously, with a second meter, the Anode Voltage across the EL-84.
This allows you to calculate the Plate Dissipation, so that you don't inadvertently set this to more than the tube is capable of. EL-84 have 12 Watts Max Plate Dissipation.
You should to place a DC meter across EL84 pins (7) Anode and (3) Cathode to measure True Cathode Voltage, as measuring the Anode to Ground is two Voltages; V tube + V Cathode Resistor = 300V.

Referring to the Tube Manuals you can never exceed the Anode Dissipation (in Watts).

So for the El84 the Max Plate dissipation is 12 Watts.

So you need to continuously plug the values into this formula to make sure that you don't exceed 12 Watts.
This means not lowering the value of the Bias Resistor Network to below that which would cause more than 40 milliamps to flow.

P = V x I (Watts) P in this case is Plate Dissipation.
Pmax = 300V x 0.040A = 12W that is maximum plate dissipation for EL84, so we know 40 milliamps, an EL-84 is breaking a sweat at idle.
But actually this is not the case as we measure the actual Anode to Cathode Voltage and get 287.1 Volts DC.
So the math actually, at 40 milliamps is taking the EL-84 right up to the Max Plate Dissipation of 12 Watts!! Ouch.
Dedsigners should always leave some headroom, and I always put my designs at 75% of Max, leaving a 25% margin.

Se we re-calculate this time again with the correct Voltage:
Pnom = 287.1V x 0.040A = 11.4 Watts that is below the max plate dissipation for EL84, but close indeed.
Lots of vintage era Hi-Fi amp designers ran the tubes quite hard, good for the Tube Business, squeeze out the Fidelity in Class A, AB.

FIXED BIAS (DE-MISTIFIED, EXPLAINED AND WAYS TO SET THIS PROPERLY):
In Fixed Bias we actually have to rectify a separate "DC biasing voltage" supply from an AC supply that provides a DC Biasing Voltage.
Another difference between Fixed and Cathode Bias is that in Fixed Bias the Bias Voltage is connected to the Input Grid, not the Cathode.

A few amps that offer Variable Biasing: Dynaco St-70, Dynaco MK3, Dynaco Mk2, Guitar Amps and many Hi-Fi Amps as well offer Variable Bias.

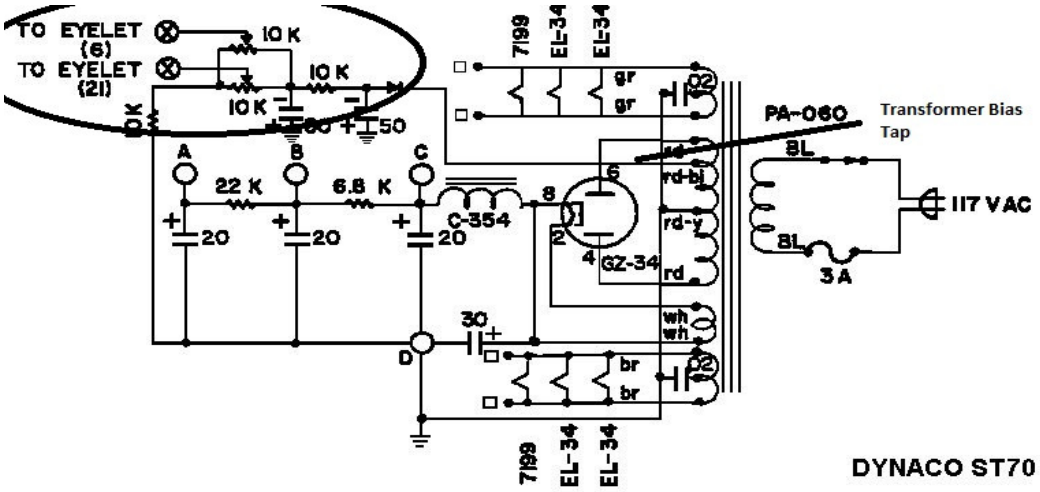
Then there are the confusing amps like the Harman Kardon A500 that is a Cathode Bias amp with I.M. Distortion nulling controls mistaken for Bias Adjustments, they are not.
The Harman Kardon A700 that is Non-Adjustable Fixed Bias and has the same two IM Distortion nulling controls that the A500 offers as well, once again these aer NOT Bias Controls or Bias Adjustments.

Finally the Fisher SA300 is a classic example of a fully adjustable Fixed Bias amp. The amp offer three different types of settings. Bias Control, DC Balance and AC Balance (a.k.a IM Distortion).

Other amps offer Bias Adjustments like the Sansui 1000A, the Pioneer Receivers and others.

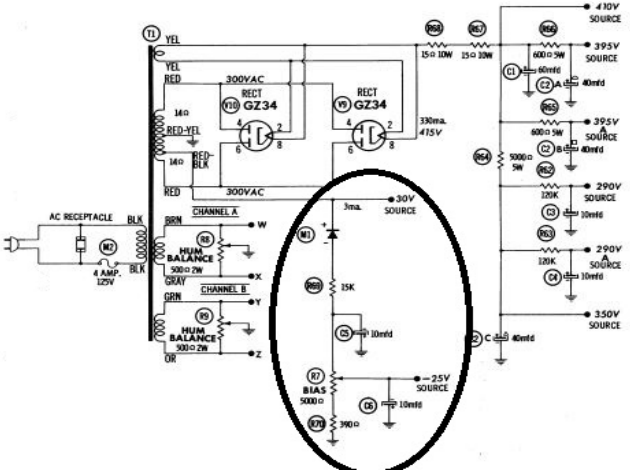
How do we know that we have Fixed Adjustable Bias?
It is very common for Fixed Bias amps to have an extra AC 55V dedicated Secondary Transformer Biasing "Tap" that offers around -30VAC after diode rectification
and allows the user to set the bias voltage level on the Input Grid of the Power Tube.

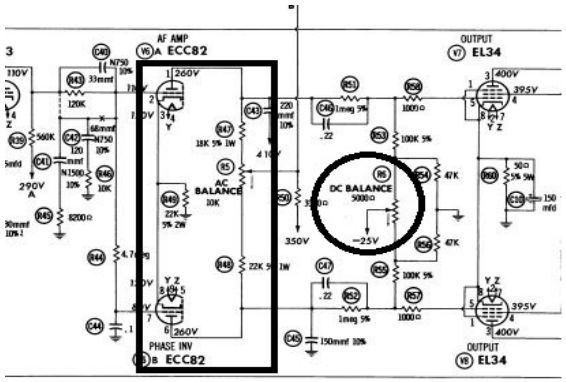
Dynaco ST-70 Fixed Adjustable Bias Circuit Example:



Above you can see that the Power Transformer has a separate tap (wire) that connects to a dedicated Bias Supply.
This is a classic Fixed Bias supply. The oval circle just sohes the connections from the 10K Bias Controls (one per channel, it adjusts 2 tubes at once).
Unless there is a dedicated bias supply with or without bias controls, the amp must not be Fixed Bias.

Fisher SA300 Bias and other:





In the above we have the famous Fisher SA300. You can see from the Power Supply that there is a wire labeled 14 Ω Red-Blk. That is a Bias Tap, same as the ST-70.
Then it produces 30V at the input to the Rectifier Diode. Then a series of resistors and a Bias Control R7 provide a adjustable bias supply of -25V according to the setting on the schematic.

So with 117VAC on the primary of the Power Transformer, you set the Bias Control for -25V at C6 by rotating the R7 Bias Control.
This is the "master bias cobntrol" or it may be the "only bias control" that you have. Some amps take this voltage with 4 wires and connect to the grid of each Power Tube Grid Resistor array.
On this amp it has a control that is called DC Balance, and it also has AC Balance.

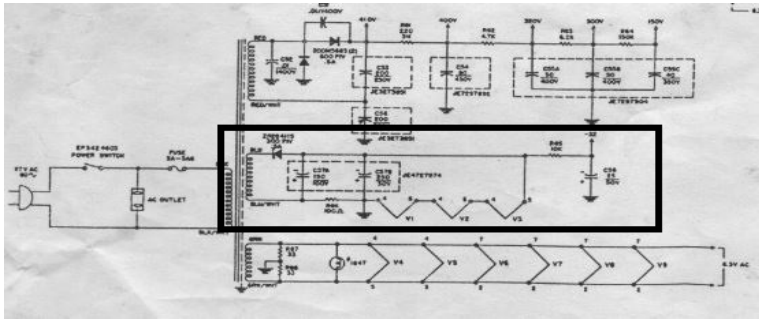
This is precisely how people get confused by the term Bias and how/where do I bias my amp.

Now that we have this example above, I can describe the following.

To set the AC Balance this is in effect the actual Phase Splitter Balance control. This is easily set using a signal generator and an IM Analyzer.
The DC Balance Control is really nothing more than a slight offset adjustment on the DC Bias Voltage, also requires a Signal Generator but the A300 has some procedures that don't require this.

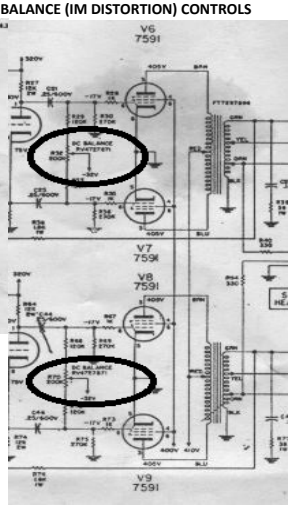
HARMAN KARDON A700 & A500:
In fact the Harman Kardon A500 and A700 amps only have a DC Balance Control (a.k.a. IM Distortion) and this confuses people into thinking that it has a Bias Adjust.
The A700 uses Fixed Bias, non-adjustable Bias Circuit. It provides that bias voltage to a DC Balance Potentiometer that is located between each set of 7591A tubes.
These controls are often mistaken for Bias. They do have a Bias Voltage on them, but they are not adjusting Bias, they are used to correct for minor DC imbalances between the output tube. This setting requires Test Equipment. Or just set them half way, in the center position, and be done with it.

A700 POWER SUPPLY



The Harman Kardon A700 has a fixed (non-adjustable) bias supply.
It is shown inside of the Black Rectangle. It makes -32VDC and that's it.

DC BALANCE (IM DISTORTION) CONTROLS



The Controls in the Ellipses are
DC Balance, not Bias.
They are like a very fine DC offset.
By changing the DC voltage by 1-3%
you can dramatically attenuate I.M. Distortion.

The -32V on the DC Balance Controls are not Bias.
The two ellipses in the diagram on the right show these:

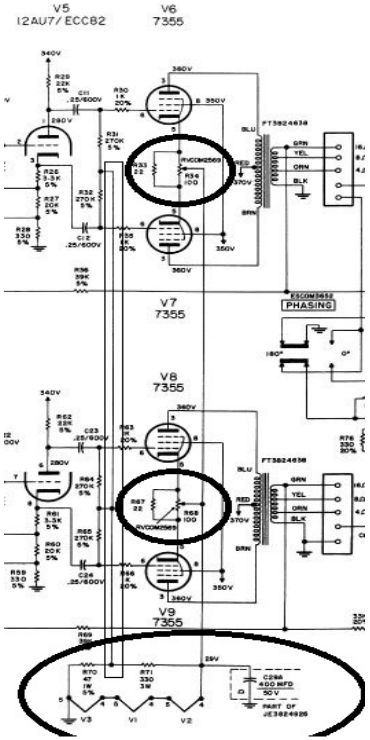
These simply wiggle the DC bias voltages up and down on each tube like a see-saw action. Turning these all the way CC or CCW is not good, it can destroy the tubes.
This control should be 12 O'clock centered
Or adjusted with an IM Analyzer/Signal Generator.
One injects into the Aux a composite signal of two tones.
This signal goes through the amp and into an Audio Dummy Load.
You Crank Up the amp into the Dummy Load and measure the IM Distortion.
You then turn the DC Balance Controls for minimum IM.
With an old meter, you just look for the lowest dip on the needle.
You will start to make the meter mre sensitive until you get the actual IM figure from the meter.
Thst figure is your lowest IM Distortio possible with those two 7591A tubes.
You can change out pairs of 7591A until you get an absolute minimum IM pair.
Setting this control with the proper test equipment lowers IM distortion and makes the music sound cleaner. But every time you change tubes, you have to re-adjust

Note that:
Fixed Bias amps have the Cathodes of the Power Tubes directly wired to DC ground, or have a small resistor in the Cathode, to be able to measure a small DC drop to set Bias levels.
Fixed Bias requires a VOM to measure Bias levels, and some amps include a Meter on the amp itself. You cannot adjust bias without a DC Voltmeter.
Fixed Bias amps have a dedicated "Bias voltage supply" connected to the Power Tubes via the input Grid Circuitry.
Fixed Bias amps can be of the *"non-adjustable"* (HK-A700) type, or made *"adjustable"* by offering a Variable Biasing Potentiometer design (rare) or modify them to add a Variable Bias Power supply and Potentiometer.

It is all the "non-adjustable" amps or some that have only DC Balance controls that can cause confusion.

A COOL EXAMPLE: UNIQUE CATHODE BIAS WITH DC BALANCE ON HARMAN KARDON A500
The Harman Kardon A500 is a hybrid type amp. It is a Cathode Bias design but offers a DC Balance to the Tubes in a unique way, thinking out of the Box.
Let me explain how this works and you will learn how to look at circuits to know what is happening in them.

Below is the popular on Ebay A500 or H50K. This is a Cathode Bias design, but a weird one to say the least.
The Cathode Current from all four 7355 Tubes is used as a Bias Voltage generator. The designer is using wasted Cathode Tube current and sending it through a 100 Ohm Linear Control that is bridged by a 22 Ohm Resistor. This arrangement takes the 7355 Cathode Currents and adds them up into R71 and the Series Connected Small signal 12AX7 Tube Filaments. Yes, the designer is lighting up the first three 12AX7's by using wasted Cathode Current and putting it into use.
The Cathode Bias voltage is 29V and availaable at the connection of R71 and C29A. The Cathoe Current flows through the tube filaments that are series connected 12 x 3 =36 Volts DC, more like 30V, that provides DC to the filaments lowering noise, especially for the Phono stage.
The only adjustable thing on the A500 is the DC Balance (not Bias). This is done with a Signal Generator and IM Analyzer.



The Controls in the Ellipse are DC Balance or IM Distortion settings, not Bias.

A500 CathodE Bias Load Circuit
The Cathode Current light's up V1, V2 and V3 plus generates 29V that in turn is referenced to the tube grids biased up by R70.
This 29 Volts is the Cathode Bias voltage that is connected to the 100 Ohm Linear Controls between the tubes.
This is a cool way to make that wasted energy work.
Somewhat like regenerative braking, we put back what we would have lost.