Early Vintage Hewlett-Packard Oscillators
1938-1941

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This is an article in progress. Revisions will be made as more information is discovered.

Introduction

Many people who have acquired or found a vintage HP oscillator have inquired to the author as to whether that oscillator could have been built in the famous garage. The answer is always no. Only a very small number of oscillators were built in the garage and typical oscillators people own have characteristics that prove that they were constructed years after the garage days. However, a recent inquiry had enough credible characteristics to inspire the author to explore deeper into the history of the oscillators and write this article. It turns out that it is almost a certainty that that oscillator was built in the garage and the author is very glad to have been able to analyze detailed pictures of it. A picture of the front of that oscillator is shown in Figure 1. It probably has been repainted at some point as the normal color was gray like shown in Figure 4 and the red fill in the engraving was probably added by some owner over the years as every example of engraved panels the author is aware of are unfilled. The original metal output binding posts have been replaced by more modern plastic versions. The author is aware of at least four of the small case units in existence.

Figure 1: A recently discovered garage vintage oscillator
(photo courtesy of Cal Taylor)

The purpose of this article is to provide all of the known information (which is not very much) concerning the earliest vintage oscillators built by the Hewlett-Packard Company.

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The early oscillators were made in four case sizes. The first oscillators from late 1938 to the roughly fall of 1939 were made in what I refer to as the small case with rounded corners which is 13” wide and shown in Figures 1 and 4. Oscillators made between the fall of 1939 and up to early 1941 were in what I refer to as the large case with rounded corners which is 16” wide and shown in Figure 16. Oscillators built from early 1941 are in the rectangular case which is 15.25” wide as shown in Figure 17. Any rack mount case is 19” wide and could have been built from 1939 onwards – a sample is shown in Figure 5. The complete dimensions are in the summary at the end. The majority, if not all, of the small case oscillators were built in the garage. The majority, if not all, of the large case oscillators were built at the 481 Page Mill Road / El Camino locations.

A summary of the early history

Bill Hewlett discovered the light bulb solution to stabilizing the Wien Bridge oscillator on July 27, 1938 (1). In the fall of 1938, Bill built an oscillator based on this design as part of his master’s thesis in Electrical Engineering at Stanford University (located in Palo Alto). Figure 2 is of the front of that oscillator now housed in a glass case at the HP Archives. The red and black output jacks are probably not the originals. Those likely wore out and were replaced at some time. Although the frequency dial resembles later 200B units (making one wonder if the original has been replaced) it is unique to this instrument and Bill must have custom made it.

Figure 2: Bill’s first Wien Bridge Oscillator at Stanford University (photo courtesy of the Hewlett-Packard Company – from web site)

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Bill and Dave and his new wife, Lucile, moved into the house on 367 Addison Avenue in Palo Alto in the fall of 1938 (2). The location was chosen because the garage could be used as a shop and there was also a small building in the backyard where Bill would live. Dave and Lucile lived in the house – see Figure 3. A state historical marker can be seen in the front yard. The famous garage can be seen behind the gate.

Figure 3: Restored HP house and garage
(photo by Ken Kuhn)

During late 1938 and part of 1939 Bill and Dave did some odd contract work including a foul line indicator at bowling alley, a synchronous motor drive for the telescope for Lick Observatory, and a self flushing toilet. This provided a little bit of income. (3)

Late in the year of 1938 the design of the model 200A was finalized and a prototype was constructed. In order not to advertise that this was their first product, the oscillator was given the model number designation of 200. The prototype was shown at the Portland IRE show in November, 1938. Bud Hawkins, the chief sound engineer for the Walt Disney Company, attended the show and was impressed with the oscillator – particularly the low price of less than one hundred dollars. Later (probably in early 1939), Mr. Hawkins contacted HP for a special version of the oscillator as discussed below. (4)

In December, Bill and Dave built another prototype in a more professional looking case. This prototype sat on the mantel over the fireplace in the house and a picture of this exists. They prepared a two-page sales brochure and sent it to a list of about twenty five contacts provided by Fred Terman. According to Bill, the first advertised price for the 200A was $54.40. That value was based on the phrase, "54'40" or fight" that was used in the 1844 campaign to set the U.S.-Canadian border in the Northwest. That price was kind of a joke amongst Bill and Dave and was not profitable. The price was later revised upwards to a profitable $71.50. (5) Bill and Dave signed the business agreement that began the Hewlett Packard Company around Jan. 1, 1939 and they began formal operations. Early in 1939 orders for the 200A began to come in. Early oscillators were built in a purchased enclosure (small case with rounded corners). It is believed (but the author has not yet found the proof) that these enclosures were manufactured by Bud Industries, Inc. (a.k.a. Bud box). (6)

On July 5, 1939, Bill and Dave donated a model 200A to Stanford University. That oscillator is now on loan to HP and resides on the mantel over the fireplace in the restored house where the first HP200A sat – see Figure 4. The author has had the privilege of a tour of the house and garage and has seen that oscillator. The small plaque below the nameplate reads, "PRESENTED TO STANFORD COMMUNICATIONS LAB." In the photograph you can see a clear plastic cover around the unit to protect it from being touched. (8)

Figure 4: Small case with rounded corners 200A oscillator (photo by Ken Kuhn)

The famous model 200B was a simple modification to the 200A requested by Mr. Hawkins from the Walt Disney Company for use in tuning theater audio systems for the upcoming move, *Fantasia*. Disney needed frequency coverage down to 20 Hz. The modification consisted of using larger resistances in the tuning network so that the frequency range of the 200B was from 20 Hz to 20 kHz whereas the frequency range of the 200A was from 35 Hz to 35 kHz (although the dial on some early units went to 40 kHz). The author has seen the only known picture (at the Agilent History Center) of the 200B units at a Disney lab and these were in the rack mount case (another modification requested by Disney) rather than the often seen desktop case. Figure 5 is a picture of a vintage 200BR model with the pre-logo nameplate just like those sold to Disney . The main chassis of the oscillator is identical to the rectangular case but the front plate is 19 inches wide to permit mounting in a standard rack. Chuck House has done some research that shows that the famous sale to Disney consisted of nine 200B units at $57.50 each. (13) The author has not found any information as to whatever became of these units as none are known to exist. (7) The author has not seen it but apparently there is a 1971 picture showing at least one of these oscillators at a Disney lab. Rack mount HP equipment includes the suffix 'R' in the model number to indicate rack mount. Thus, the units sold to Disney are really 200BR although it is not known if the suffix was first used in 1939.

Figure 5: HP200BR S/N 478 similar to those sold to Disney (photo by Tim Souza)

Figure 6 shows a close-up of the name plate on early HP oscillators like the one in Figure 3. This nameplate style was used from the earliest oscillators up to early 1941 when the new HP logo was introduced. Any HP equipment that does not include an HP logo and has a nameplate similar to that in Figure 7 was definitely manufactured prior to 1941.

Figure 6: Pre-1941 name plate prior to introduction of HP logo
(photo by Glenn Robb)

Figure 7 shows a typical nameplate for equipment made between 1941 and 1945 and also shows the first logo for HP introduced in early 1941. Any HP equipment that includes an HP logo was definitely manufactured from 1941 onwards.

Figure 7: HP nameplate style used between 1941 and 1945
(photo by Ken Kuhn)

Figure 8 shows a picture of Bill and Dave in the garage and is the only known garage picture. Dave is sitting and holding a slide rule. This pose cleverly hides the fact that Dave was significantly taller than Bill. The author has had the privilege of a tour of the restored garage and has stood in the very spot shown. An oscillator in the rack mount case (like was sold to Disney) can be seen on the left of the table. To the right is some kind of instrument in the small case with rounded corners. That instrument is not one of the classic oscillators as the panel layout does not match any known instrument. It looks like it might have been an oscillator (perhaps experimental) with a different panel layout. Behind that unit are two of the large cases with rounded corners used for oscillators probably after the summer of 1939. Although the oscillators have a kind of greenish tint in the picture, that is believed to be a color flaw in the photograph. The oscillators are likely the gray color shown in Figure 4. The workbench would likely be gray too.

Figure 8: Bill and Dave in Garage
(photo courtesy of the Hewlett Packard Company)

More space was needed because the business was expanding. While still in the garage they hired Harvey Zieber who was their first employee. According to Packard (9), in the fall of 1939 they moved the operations from the garage to a small building at 481 Page Mill Road that was behind Tinker Bell's Fix-it Shop that was located at the corner of Page Mill Road and El Camino Real. That first rented building can be seen in Figure 9. The sign reads Electrical Engineering & Manufacturing. HP occupied this building from the fall of 1939 to early 1942.

Figure 9: HP at 481 Page Mill Road, circa 1941
(photo courtesy of the Hewlett-Packard Company)

Figure 10 shows that same build when occupied by Polly and Jake. It is not presently known if this picture was taken before 1940 or after 1942 when HP moved to the newly constructed Redwood building.

Figure 11 shows that building as seen in 2006. The front entrance has been closed off. The side door and window to its right may be the same as can be seen in Figure 17 where Dave is operating a model 300A wave analyzer. The house on the left is the same that can be seen in the Polly and Jake picture in Figure 10.

Figure 10: An old picture of the first building HP rented
(photo courtesy of the Hewlett-Packard Company)

Figure 11: Picture of 481 Page Mill Road in 2006 (photo by Ken Kuhn)

In 1940, needing even more space, HP expanded into the front of Tinker Bell's Fix-it Shop. Figure 12 shows the building on the corner of Page Mill Road and El Camino Real as seen in 2006. This was the Tinker Bell Fix-it Shop building that HP expanded into during 1940.

Figure 12: The Tinker Bell Fix-it Shop as seen in 2006
(photo by Ken Kuhn)

Figure 13 shows a view from Across Page Mill Road of both buildings that HP expanded into in 1939 and 1940 as seen in 2006. Sadly, these buildings were demolished in August of 2009.

Figure 13: The first two buildings that HP occupied as seen from across Page Mill Road (photo by Ken Kuhn)

In 1942, HP moved into the 10,000 square foot building they constructed at 395 Page Mill Road. This building was known as the Redwood building because redwood was used for the siding. (12)

Figure 14: Redwood building at 395 Page Mill Road

Figures 15a and 15b show advertisements for an HP200B in the November, 1939 issue of Electronics magazine. One ad shows the small case and the other shows the large case. This suggests that by the fall of 1939 that the transition to the larger case was being made. An interesting question would be why the case change was made. It is the author's opinion that the small case probably ran a bit warmer than desired and the larger case permitted lower internal temperatures. Or, maybe the small case was deemed too cramped. Note the price of $71.50 in both ads.

Figure 15a: Model 200B ad in small case

(scanned from Measure Sept/Oct. 1964)

Figure 15b: First advertisement in Electronics magazine, November, 1939 issue (scan courtesy of Marc Mislanghe)

It is interesting that there were ads for both case sizes in the same November issue of Electronics in 1939. Both ads show the 367 Addison address instead of the new 481 Page Mill Road address that the operation had moved to. The most likely explanation is that at the time the ad was submitted the operation was still in the garage and the move to Page Mill Road was not established.

Figure 16 shows the oldest 200B oscillator in the author's collection. It is in the large case with rounded corners like the advertisement shown in Figure 15b. It has the newer style name plate with the hp logo that was introduced in 1941 thus dating the instrument. Including the one he owns, the author is only aware of three of these units in existence. It is believed that more will be discovered someday. It is likely that many hundreds of these were made before the switch to the rectangular cabinet.

Figure 16: Large case with rounded corners, HP200B s/n 829 in the author's collection, circa 1941 (photo by Ken Kuhn)

At some point, probably around late 1940 to early 1941, HP began manufacturing their own rectangular case instead of purchasing the rounded corner cases. An example is shown in Figure 17. This particular oscillator is unusual in that it had a fine tuning knob to the left of the main tuning knob and is the only oscillator the author has ever seen with that feature. This oscillator from the author's collection was loaned to the California Museum in Sacramento for a year long exhibit in 2007 honoring David Packard. The picture of Dave operating a model 300A wave analyzer that was most likely taken in the 481 Page Mill Road building and the window is either facing the rear of the building or towards the back of the Tinker Bell building (see the right side of the building in Figure 11). The Addison garage has no windows.

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Figure 17: Early HP200B oscillator in rectangular case on display at the California Museum in Sacramento (photo by Ken Kuhn)

Summary of the oscillators

Dimensions:
Small case with rounded corners dimensions: 13”W x 8”H x 9”D
Large case with rounded corners dimensions: 16”W x 8”H x 9”D
Rack mount case dimensions: 19”W x 7”H x 9”D, main enclosure 15”W
Rectangular case dimensions: 15.25”W x 7”H x 9”D

Specifications:

Model	Band	Frequency range	Output power
200A	X1	35 – 350 Hz	1 watt into 500 ohms
	X10	350 – 3,500 Hz	
	X100	3,500 – 35,000 Hz	
	Note: some early 200A dials went to 400 instead of 350		
200B	X1	20 – 200 Hz	1 watt into 500 ohms
	X10	200 – 2,000 Hz	
	X100	2,000 – 20,000 Hz	

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The introduction dates of the 200C and 200D are not known but believed to be sometime between late 1940 and early 1942. These oscillators provided extended frequency coverage into higher frequencies and lower frequencies. Both models are based on the same lamp stabilized oscillator circuit of the 200A. These two models do not have as much appeal to collectors as the 200A or 200B but they should as each are based on the same circuit as the 200A and only lack a power amplifier and transformer since such was not practical at that time for the extended frequency coverage.

Model	Band	Frequency range	Output power
200C	X1	20 – 200 Hz	100 mW into 1000 ohms
	X10	200 – 2,000 Hz	
	X100	2,000 – 20,000 Hz	
	X1000	20,000 – 200,000 Hz	
200D	X1	7 - 70 Hz	100 mW into 1000 ohms
	X10	70 – 700 Hz	
	X100	700 – 7,000 Hz	
	X1000	7,000 – 70,000 Hz	

Although out of the scope of this paper, it is appropriate to briefly mention other oscillator models developed in the 1940s all based on the original 200A design but with differing frequency ranges and output power levels. By the end of the 1940s HP oscillators covered the frequency spectrum from 0.5 Hz to 10 MHz – a twenty million to one spread. The oscillators that included frequency coverage below 20 Hz were targeted to seismic research. None of these oscillators were sold in the either the small or large case with rounded corners. All were sold in either rectangular or rack mount cases. Wooden oak cases were used to make desk top versions of rack mounted versions such as the 205.

200I ('I' was for interpolation) had narrower frequency bands for finer frequency resolution.

200H ('H' was for high frequency) Similar to the 200C but could tune from 60 Hz to 600 kHz.

201B A high power version of the 200B that could produce 5 watts to a 600 ohm load.

202B Used a total of 16 variable capacitor sections to tune down to 0.5 Hz – the lowest of any Wien bridge oscillator design. The upper frequency was 50 kHz.

202D Similar to the 200D but tuned down to 2 Hz and up to 70 kHz

205A, 205AG, 205AH These were audio test stations that included a 201B oscillator, one or two 400A voltmeters, and a 350B attenuator.

206A This was a special version of the 200B that achieved ultra low distortion (0.1% maximum) by using a tracking filter on the output of the oscillator.

650A This was a wide range oscillator that could produce signals from 10 Hz to 10 MHz. The 10 Hz to 1 MHz ranges used the classic Wien Bridge oscillator design. The 1 to 10 MHz range used a ring oscillator suggested by Barney Oliver, a class mate of Bill and Dave who would later be hired by HP.

Conclusions:

- Any small case with rounded corners oscillator was likely built in the garage during the first nine months of 1939. The total number of these is believed to be approximately 30. No evidence of small case oscillators has been found after that time period. More research is needed.

- It is believed that only 200A units were built in the small case with rounded corners. No 200B units in the small case have ever been located.

- The first nine 200B units were in a rack mount case and built in the garage.

- Later 200A and 200B units after the fall of 1939 were built in either the large case with rounded corners or rack mount depending on the customer's request.

- The introduction of the rectangular case is believed to be in early 1941 since no rectangular case units have been located with the pre-1941 name plate.

Estimated production for 1939

The total revenue for 1939 is known to be $5369. There are three components of this total; oscillators manufactured in the garage, oscillators manufactured at the 481 Page Mill Road location after the fall of 1939, and other revenue from some engineering projects at either location. It is hoped that someday the exact details will become known but for now the best that can be done is estimation. The original price according to Bill was $54.40 although it is not known how many were sold at this price as the price was later revised upwards. The following is the author's best estimation of the oscillator production for 1939 based upon low initial sales early in the year and climbing through out the year especially after mid year. Obviously, there are a variety of number sets that could attain the same total but this set feels right. More research is needed.

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Quantity	Description
~30	200A oscillators in the small case with rounded corners built in the Addison garage and sold for $54.40 or $57.50 each during from January through about August. Revenue total: ~$1,700.
9	200B oscillators in the rack mount case built in the garage and sold to Disney for $57.50 each. Revenue total: $517.50.
~37	200A/200B oscillators in the large case with rounded corners built at the 481 Page Mill Road location from about September through December and sold for $71.50 each. Revenue total: ~$2,650.
~$500	Estimated revenue for other project work.

~74 total oscillators sold during 1939, ~39 at the garage and ~37 at the 481 Page Mill Road location. The total revenue above is approximately the actual known value.

Oscillator and light bulb

This is a very brief discussion for non-technical people of what an electronic oscillator is and why a light bulb is a significant component. The discussion focuses on audio applications because that is what the first HP oscillators were used for. In the most classical sense an electronic oscillator generates a periodic waveform known as a sine wave – see Figure 18. Unlike a rich musical tone, a sine wave consists of only the fundamental frequency without any harmonics. Except for special effects, an audible sine wave is considered to be a boring and uninteresting sound. However, it is the lack of harmonics that makes the sine wave very useful for testing audio systems. All audio systems will produce distortion. For a sine wave input the distortion shows up as harmonics on the output. The degree of distortion can be determined by measuring the amplitude of these harmonics. Thus, a sine wave generator is a valuable testing tool for audio systems and that is why Disney was interested (the low price was factor too).

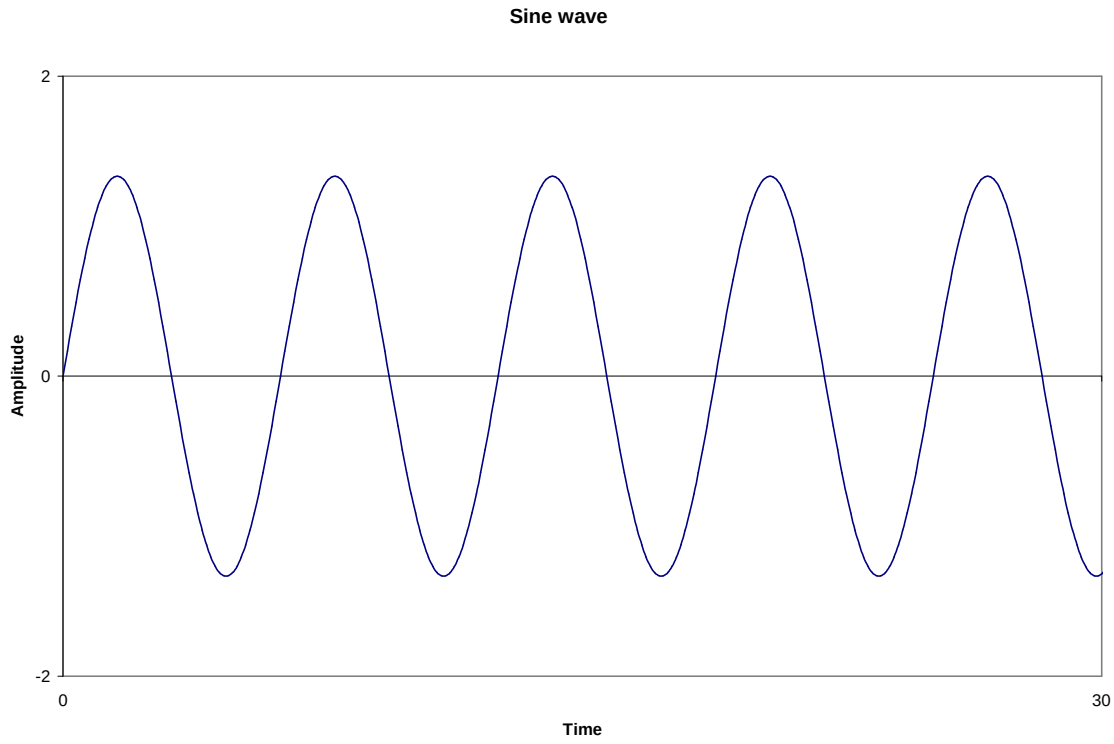

Figure 18: Sine wave

A basic Wien bridge oscillator is shown in Figure 19 and consists of

- a high gain amplifier (exact value is not important).
- a positive feedback path that produces a zero degree phase shift at a single frequency (resonance) determined by the resistance, R, and dual variable capacitor, C, driven by the front panel tuning knob.
- a negative feedback path consisting of the voltage divider formed by R1 and R2. R2 is the resistance of a light bulb.

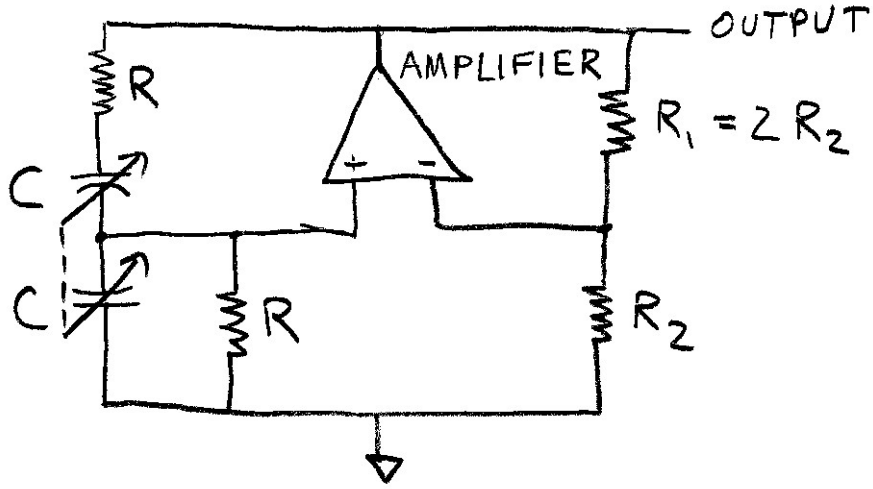

Figure 19: Wien bridge oscillator

Skipping the complex math, at resonance the amplitude of the positive feedback path through the network of resistors and ganged variable capacitors is one-third that of the output of the amplifier. The negative feedback path through resistors R1 and R2 will also produce a one-third factor if the components are exactly as shown. If the positive and negative factors are exactly the same then a stable oscillation is produced at the resonant frequency. In practice it is impossible to manually adjust both factors to be exactly the same. If the positive feedback factor is higher than the negative, then the oscillation will grow in amplitude until the amplifier saturates and a flat topped wave is produced. If the positive feedback factor is less than the negative, then the oscillation will either never start or will quickly decay to zero. Either way, the result is a bunch of useless electronics. If a method could be found to make the two feedback paths exactly match then the electronics becomes very useful. Necessity is the mother of invention.

The filament of a light bulb has the characteristic that its electrical resistance increases with temperature and the temperature increases with applied power. If a light bulb filament is part of the R2 circuit in Figure 19, then the power applied to the light bulb increases with the amplitude of the output oscillation signal from the amplifier. What this means is that if the amplitude is too low the power applied to the light bulb will be low resulting in a low filament temperature and low electrical resistance. Low electrical resistance results in a low negative feedback factor. Thus, the positive feedback factor exceeds that of the negative and the output amplitude increases as previously discussed. But, that increase in output amplitude results in an increase in the power applied to the light bulb, an increase in the filament temperature, an increase in its electrical resistance, and an increase in the amount of negative feedback applied. An operating point is reached where there is perfect equilibrium in the positive and negative feedback factors and a pure and stable sine wave is produced. The only other requirement is that the filament temperature response time be long compared to the frequency of oscillation – otherwise the sine wave would be distorted. Bill's invention was to incorporate a light bulb in the R2 circuit to produce this equilibrium. This incredibly simple concept made the Wien bridge oscillator possible. It should be noted that the operating point on the

light bulb filament is at a low temperature where the resistance change is very dramatic. Thus, the light bulb is not glowing (or barely glowing as observed in the dark) and essentially lasts forever. Bill's thesis describes all the electronic considerations necessary for this oscillator to work.

Licensing and patent information on HP oscillators

There are two patent references on the back of vintage HP oscillators. One statement is to the effect that the oscillator is manufactured under a license from Western Electric which owned a variety of patents pertaining to vacuum tubes and other electronic devices. The patent number 2,173,427 pertains to a general electronic oscillator and illustrates a Wien bridge as used in all early HP oscillators. Bill did not invent the Wien bridge oscillator – he invented a method to make it work well and patent 2,268,872 is the Hewlett patent for using a light bulb to stabilize the oscillator. So HP oscillators were licensed under 2,173,427 (owned by Western Electric) and manufactured under 2,268,872 (owned by HP).

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