Heathkit of the Month #33:
by Bob Eckweiler, AF6C

Heathkit SB-200 / SB-201
HF 1KW Linear Amplifier.

Figure 1: Heathkit SB-200 Linear Amplifier

Introduction:
"More Power Scotty; we need more power!" Have you ever wanted to scream that as you are trying to break through the pile-up for that rare DX contact you still need. Sure, you have that transceiver with 100 watts output, but you know you could make the contact more easily with a kilowatt. Wouldn't that mean another S-unit or two?

Before SSB became the popular choice for HF voice communications on the ham bands, amplitude modulation (AM) was the mode most often used. Operating a kilowatt on AM was a big deal. There are linear RF amplifiers and class-C RF amplifiers. The linear amplifier has an efficiency of between 50% and 60% but amplifies the input signal accurately. Class-C amplifiers on-the-other-hand are 75% to 85% efficient but heavily distort any modulation on the input signal. What it does do well is amplify a CW signal.

Thus the typical kilowatt of the day ran class-C with one kilowatt input power that was plate modulated by a high power audio signal of about 50% of the RF power or 500 watts PEP. Thus the kilowatt amplifier would output an 800 watt carrier with about 200 watts in each AM sideband. A linear amplifier was not used since it would not be nearly as efficient and would have to operate at a 100% duty cycle while transmitting. Also transmitting tubes of the era were designed to run class-C and not too many of them really performed well when biased for linear operation. Class-C works well for CW, FM and RTTY too. Since the duty cycle of the carrier is 100% a Class-C kilowatt's power supply is massive, having to supply not only power for the carrier but power for 500 watts of PEP audio too - a combined average power of about 1,200 watts during transmit.

When SSB became popular so did the linear amplifier. A SSB signal is usually generated at a fixed frequency and a low power level and then heterodyned to the desired operating frequency where it is amplified linearly to the desired output power. The linear amplifier on SSB only has to amplify the one sideband. Thus a kilowatt linear on SSB can produce about 600 watts output on the selected sideband. With SSB communications becoming popular for military, commercial and ham communications, the tube manufacturers redesigned many of their tubes for better linear performance. Two in particular stand out for ham use. They are the Eimac 3-500Z and the United Electronics 572B (or the identical Cetron T-160L).

Model (Name)	From	To	Final Tube(s)
KL-1* (Chippewa)	1959	1960	4-400A x 2
HA-10 (Warrior)	1961	1965	811A x 4
SB-200	**1964**	**1978**	**572-B x 2**
HA-14*	1965	1968	572-B x 2
SB-220	1970	1978	3-500Z x 2
SB-230	1974	1978	8873 x 1
SB-201	**1978**	**1983**	**572-B x 2**
SB-221	1978	1983	3-500Z x 2
HL-2200	1983	1984	3-500Z x 2
SB-1000	1987	1992	3-500Z x 1

** (external power supply required)*

Table 1: Heathkit HF Amplifiers

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Since linear amplifiers, draw power on SSB at the audio duty cycle (often approximated at 30%) or on CW at the key down rate, the power supply can be much less stringent than for AM. Also the development of Hypersil transformers with their size to power advantage allows the manufacturer to incorporate the power supply in the amplifier cabinet if desired.

Heathkit saw the need for HF power amplifiers in the ham community soon after SSB became popular and produced a line of them. The two outstanding amplifiers are the SB-200 and the SB-220. Each of these deserve their own article. The others may be the topic of a later compound article. Table 1 lists them (with the SB-200/201 and SB-220/221 included to show the timeline):

The Heathkit SB-200:
The Heathkit SB-200 (see Figure 1) was announced in July 1964, for late August delivery, (See Figure 4) at a kit price of $200 to complement the SB-300 receiver and SB-400 transmitter. It not only matches their style, it also fits in the same size cabinet - and that includes the power supply. The SB-200 was produced until 1978 when FCC rules required a change to all HF linear amplifiers. The changed version with the nomenclature SB-201 was produced for another five years until 1983 - a total of run of 20 years! In 1973 the kit price was $229 and in 1983 it sold for $479.95.

The SB-200 is specified at 1,200 PEP watts input on SSB and 1,000 watts on CW. The efficiency of linear amplifiers are around 60% so the power to the feedline can be expected to be on the order of 820 watts PEP and 700 watts CW. (This includes the 100 watts from the exciter which is fed through the amplifier.) The SB-200 covers the five non-WARC amateur HF bands from 80 meters through 10 meters.

Power Supply:
Figure 3 is a schematic of the SB-200. The power supply transformer has three secondaries. A high current 800 volt HV secondary for the voltage doubler circuit. A low current 120 volt secondary winding for bias voltage and to operate the antenna relay. And a 6.3 volt center-tapped winding to provide 8 amps of filament current for the tubes. The primary has dual 120 volt windings that can be wired in parallel for 120 VAC operation, or in series for 240 VAC operation. The 120 VAC cooling fan is connected across one of the 120 VAC transformer windings.

Figure 2: Cetron 572B Tube

Plate-voltage is produced by a full wave voltage doubler circuit consisting of sixteen silicon diodes in two series chains of eight. Filtering is by six electrolytic 125 µF 450 volt capacitors in series. Each capacitor is shunted by a 30KΩ 7-watt bleeder resistor. The capacitor closest to ground potential has an additional 700Ω resistor in series with its bleeder resistor. The 10 volts that is tapped off at this point is used to set the ALC threshold. The negative end of the high-voltage power supply is connected to ground through a 1Ω power resistor. This resistor is a shunt for measuring the plate current. The voltage doubler provides around 2,000 VDC at a 500 ma load, and the effective filter capacitance is 21 µF.

The bias supply produces approximately a negative 100 VDC which is fed through the change-over relay coil to the grids of the tubes and also to a 33Ω resistor to the external **ANT RELAY** connector (the relay coil is shunted with a 2,700Ω resistor). When not transmitting the minus 100 volts is applied to the grids of the tubes to cut off any plate current. Since no current is being drawn by the grids, no current flows through the relay coil and the relay remains in the bypass position. When transmitting, the **ANT RELAY** lead is grounded by

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contacts on the external transmitter causing current to flow in the relay and switching the amplifier in line. The bias on the grids drops from -100V to about -2 volts, the voltage drop across the 33Ω resistor. This bias voltage is applied to the grids and sets the quiescent plate current for the final tubes (about 90 ma.)

Final Tubes:
One of the early era tubes that does well in linear mode is the 811A triode from RCA. This amplifier uses two 572B (T-160L) high-mu graphite plate triodes (see Figure 2), a design improving on the 811A; each tube is capable of 160 watts of plate dissipation. These tubes are connected in parallel running class-B in a grounded grid configuration. The grids are grounded to RF by bypass capacitors but are at a DC potential - a negative 2V bias during transmit and a negative 100V cutoff bias during standby. The loaded plate voltage is on the order of 2,000V. RF drive is provided to the directly heated cathodes. The tubes are mounted horizontally in the cabinet and an electric fan provides the necessary cooling.

Driving Circuit:
Normally the change-over relay is open and the amplifier circuit is bypassed so the input and output RF connectors are connected together through a built-in SWR bridge. When the **ANT RELAY** connector on the back of the amplifier is grounded the relay operates and RF from the exciter is fed to the input circuitry. The input circuitry consists of a broadly tuned factory aligned pi-network circuit for four of the five bands, selected by the band switch. An "L" network is used on 80 meters. The RF is then fed though a capacitor to the cathode of the two tubes. These tubes use a directly heated cathode (i.e. the cathode and the filament are the same tube element) and are designed to warm up instantly. A bifilar wound choke isolates the RF section of the cathode from the filament winding of the power transformer.

Output Circuit:
The amplifier output circuit is a common pi-network. Tuning is by a high voltage 150 pF variable capacitor. Loading is by a dual 457 pf variable capacitor. On 80 meters padding capacitors are switched in parallel with each of the variable capacitors. Inductance for the pi-network is provided by two tapped coils, an air-wound coil for 10 and 15 meters and a coil wound on a ceramic form for 20, 40 and 80 meters. Band selection is by a wafer on the band switch that selects the correct coil segment and on 80 meters switches in the padding capacitors A 5KV bypass capacitor isolates the DC plate voltage but lets RF pass to the pi-network. Should that capacitor fail a 1.1 mH choke across the RF output will short out the HV tripping the circuit breaker. During transmit the output of the pi-network is fed to the **ANTENNA** connector on the rear panel after passing through the built-in SWR bridge.

ALC Circuit:
The SB-200 amplifier provides automatic level control (ALC) feedback to the exciter. RF energy is coupled through a capacitive voltage divider from the grid of one of the tubes. When the voltage exceeds the ALC voltage a diode conducts and the resulting negative voltage is filtered and appears on the ALC connector on the rear panel. Heathkit transceivers and exciters have an ALC input that allows this voltage to lower drive and prevent the amplifier overdrive, a cause of distortion and unwanted interfering emissions.

Metering Circuits:
The single 200 µA (1,400Ω) meter on the front panel of the SB-200 allows measurement of grid current, plate current, high voltage, relative output and SWR. Grid current is measured across a 1.5Ω shunt resistor in the grid circuit. Plate current is measured across a 1Ω shunt resistor in the power supply divider chain and a 3,600Ω series resistor. High voltage is measured through a series chain of three 4.7 MΩ resistors, with a 15KΩ resistor shunting the meter. The other two meter positions are for the built-in Heathkit SWR bridge whose circuit will be discussed in a future series.

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Building the Heathkit SB-200:

A lot of the fun of a Heathkit is in the building; something lost on today's instant gratification culture. The kit takes about 16 - 20 hours to build, though some do it (probably less successfully) in 12 hours. The satisfaction when you successfully finish is worth the time.

After inventorying and familiarizing yourself with the kit's parts, the HV circuit board for the power supply is assembled. The board holds the rectifier diodes, electrolytic capacitors and their associated resistors. Next, components such as the transformer, connectors, terminal lugs variable capacitors, the completed circuit board, and others are mounted on the main chassis.

The main chassis is put aside momentarily and parts are mounted on the RF shield including the tube sockets, more terminal strips, the tank coils, and bandswitch, which is assembled in sections on either side of the shield wall. Then the wiring and wired components confined to the RF shield are installed. The RF shield and main chassis are joined, and the chassis bottom is wired. To ease wiring Heath often provides an assembled wiring harness with their kits; this is installed and wires from the various "breakouts" are connected. Additional components are added below the chassis as is the power cord during the "chassis bottom wiring". The SWR bridge components are assembled next; they fit in a shielded area on the inside back chassis.

After some additional structural chassis components are added, chassis top wiring is started; this is mostly confined to the RF compartment where, along with more wiring, the final tubes are installed and their plate caps wired in. Then the meter is mounted on the front panel and the front panel is attached and wired to the main chassis.

Finally the input coils are mounted to the rear of the RF shield and the input wiring is completed, including the bifilar RF filament choke. And the needed cables to connect the amplifier are assembled.

Initial checks are then run. First is a resistance check, followed by the real pièce de résistance - the power is turned on! If the tube filaments light, the meter on HV reads around 2400V and you are not greeted with smoke, flame or a sharp noise, you are on your way to success. After safety steps to be sure the unit is unplugged and the capacitors discharged, the top shield is installed, safety labels are put in place and the amplifier is installed in its cabinet.

The manual then describes installation and operation. It's time for tuning the amplifier in anticipation of that first QSO.

The Heathkit SB-200 on the Air:

Though the SB-200 was designed as a companion for the Heathkit exciters and transceivers of the sixties, seventies and eighties, it quickly became popular in use with other manufactured radios, and is still popular today. If you are using the SB-200 with any of today's transceivers there are a few things you need to take into consideration. First, the **ANT RELAY** connector requires that -120 volts be switched to ground to enable the amplifier. This was easily handled by a relay in the exciter, but most of today's solid-state radios use a transistor instead of a relay and won't handle that high a voltage nor that polarity. There are kits available that add a simple circuit board inside the SB-200 to allow low voltage switching [1]. The nice thing about most of these "low voltage switching" kits is that they continue to allow operation with the older radios with relays.

Operating the SB-200 is a pleasure. The instant warmup of the tubes allows you to go from low power to high power instantaneously, assuming you are tuned up on the band near your current frequency. The tuning is broadband enough that an mild excursion of frequency can be accomplished without retuning. Of course this also depends on the antenna in use and whether you are using an antenna tuner.

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Heathkit SB-201:
In 1978 the FCC, fed up with all the high power illegal operation by CB enthusiasts on 11 meters, and even on frequencies above 11 meters and into the 10 meter band, passed a law that made it illegal for manufacturers to sell amplifiers that have 10 - 11 meter capability. Thus the SB-201 was born. It is almost identical to the SB-200 with certain changes. The most obvious is that the front panel is missing the 10 meter mark on the band switch. The band switch and input and output circuits are also modified to remove 10 meters. Finally a riveted filter has been added to the input line to filter out 10 and 11 meter signals. Heathkit, with FCC approval, allowed hams to buy the parts to add 10 meters if they ordered the needed parts and sent along a valid copy of their ham license.

Modifying, Restoring the Heathkit SB-200/201:
Besides returning the 10 meter band to the SB-201 there have been a lot of articles published in the various ham magazines on modifications to this amplifier. Operation on 160 and 6 meters as well as the WARC bands have all been discussed. (If you are planning on putting the SB-200 on six meters, just be advised that the tubes are rated for 30 MHz for full output.) Still, these articles all attest to the popularity of this amplifier.

In addition to the many articles, numerous pages on the web are dedicated to restoring this amplifier. Many of these are informative but I did come across a few that offered bad advice. One recommended replacing the 125 µF filter capacitors (a total capacity of 21 µF) with 470 uF units (a total capacity of 78 µF). The author stated that the amplifier "surged" when turned on but the circuit breakers tripped only "occasionally". Since resetting a circuit breaker involves raising the top cover (two screws) and removing the top shield (and its 21 sheet-metal screws), "occasionally" seems way to often. Besides the surge taxes the transformer and the doubler diodes; bigger isn't always better. A reputable company, Harbach Electronics has a kit that replaces the HV circuit board, and they upgraded the capacitors to 180µF, (a total capacity of 30 µF) a much more reasonable value; their board also includes higher performance diodes, precision metering resistors and a more efficient bleeder resistor chain.

Another place on the web, (or it might have been the same site) comments that the filament voltage at their tubes measures only 4-1/2 volts instead of 6.3 volts. They say this is okay; I say either their voltmeter is broken, the transformer is shot or, most likely there is a bad connection in the filament circuit. The filaments draw 8 amps so a bad connection less than a quarter ohm will drop the voltage down to 4.5 volts. Running these tubes on such a low filament voltage will damage the emission capability of their thoriated tungsten filaments; the specs say 6.3 V ±0.3V. If it were my amplifier I'd find the real problem.

So beware of some of these Internet sites if you are going to update a kit. Also be cautious of the high voltage in the amplifier. It has a lot of amperage capability behind it and is likely fatal if you get across it.

Harbach Electronics [1] and RF Parts [2] are good sources for accessory and replacement parts.

73, from AF6C

Notes:
1. Harbach Electronics:
http://www.harbachelectronics.com
2. RF Parts: http://www.rfparts.com

Remember if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.
Thanks - AF6C

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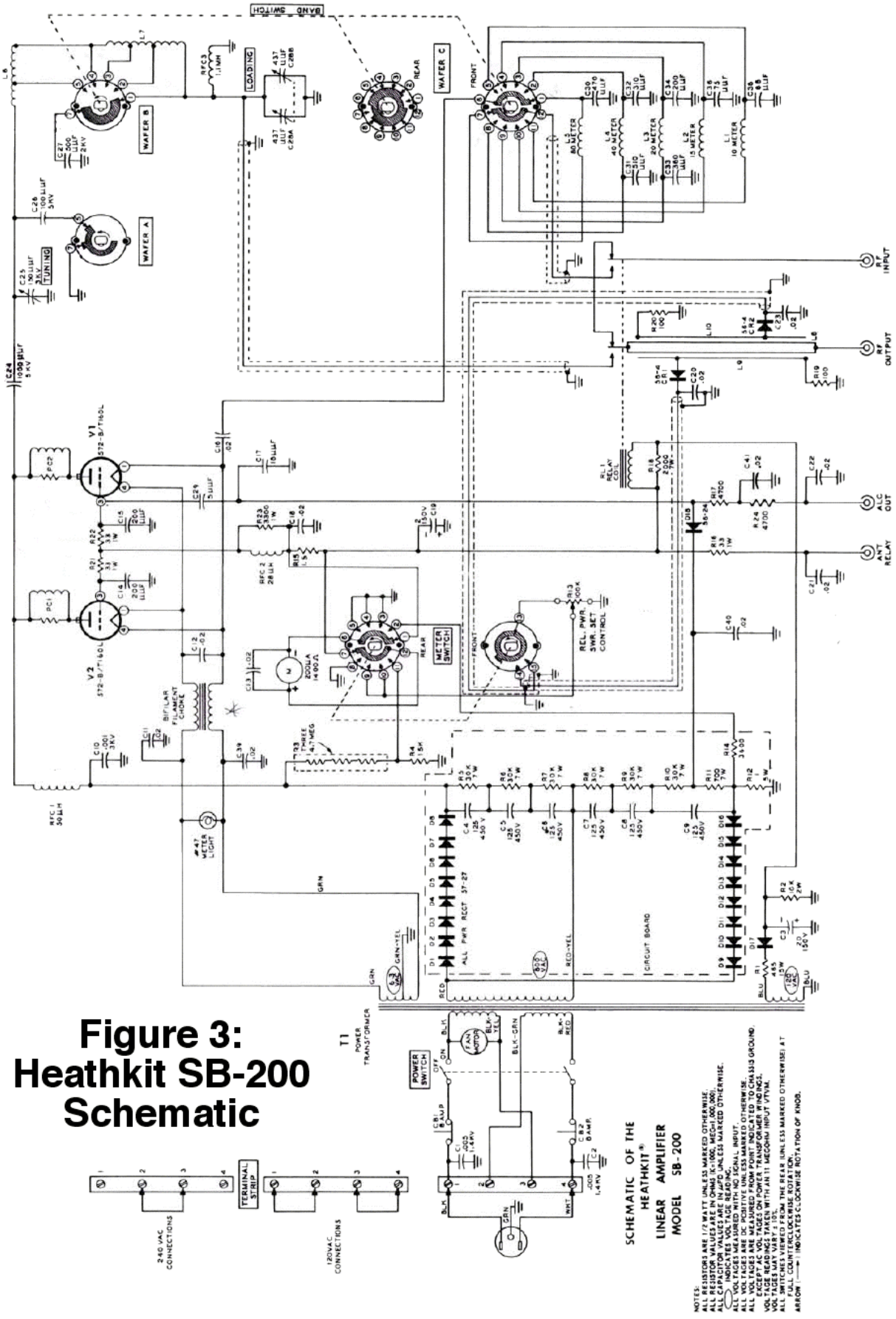

Figure 3: Heathkit SB-200 Schematic

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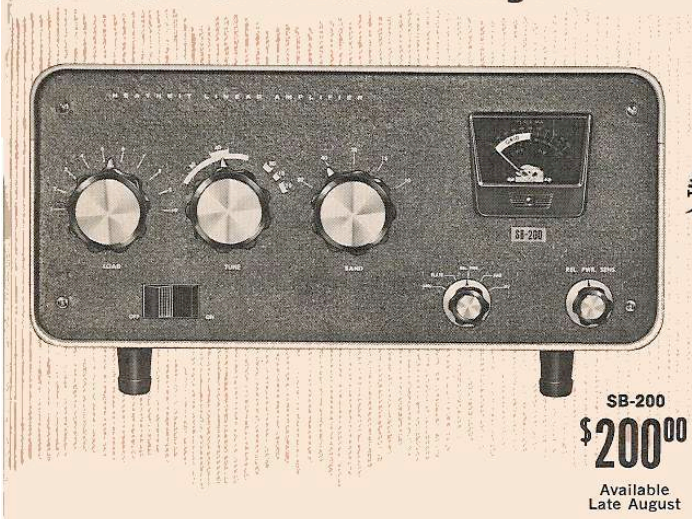
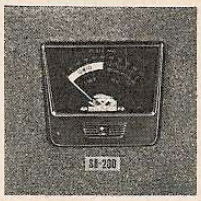
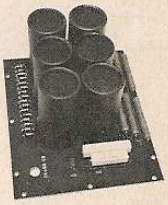


SB-200
$200.00
Available
Late August



BUILT-IN PANEL METER
Measures grid current, plate current, relative power output, SWR (standing wave ratio) and high voltage (switch-selected) for simple tune-up and maximum operating efficiency.



SOLID-STATE POWER SUPPLY
Long-life silicon rectifiers and high capacity filter assure smooth DC output and excellent dynamic regulation. All parts mount on a heavy-duty circuit board for easy assembly.

Heathkit SB-200 Kilowatt Linear Amplifier . . . Latest in this Deluxe SSB Amateur Series!

• 1200 watts P.E.P. SSB—1000 watts CW • 80 through 10 meter band coverage • Built-in SWR meter—Antenna relay—Solid-state power supply • Automatic Load Control (ALC) • Shielded, fan-cooled amplifier compartment • Pre-tuned cathode input circuit for maximum efficiency & low distortion • Circuit-breaker power supply protection—no fuses • Designed for 120/240 volt operation

Here is the latest addition to the sensational new Heathkit deluxe SSB amateur series . . . a completely self-contained desk-top KW Linear Amplifier that is handsomely styled to match the new SB-300 Receiver and SB-400 Transmitter.

Neat, compact and transportable (only 35 lbs.), the SB-200 Linear provides 1200 watts P.E.P. in a high efficiency grounded-grid circuit for greatly-extended amateur communications.

The many advanced design features incorporated in the SB-200 include a pre-tuned cathode input circuit for maximum efficiency and low distortion . . . ALC output for automatic exciter control . . . a rugged, conservatively rated solid-state power supply, protected by circuit-breakers (no fuses to replace or worry about) . . . two heavy-duty 572B/T-160-L final amplifier tubes, fan-cooled for maximum life . . . complete shielding for maximum TVI protection and stability . . . plus a built-in SWR meter and antenna relay. The antenna is automatically transferred to the exciter when the linear is switched "Off."

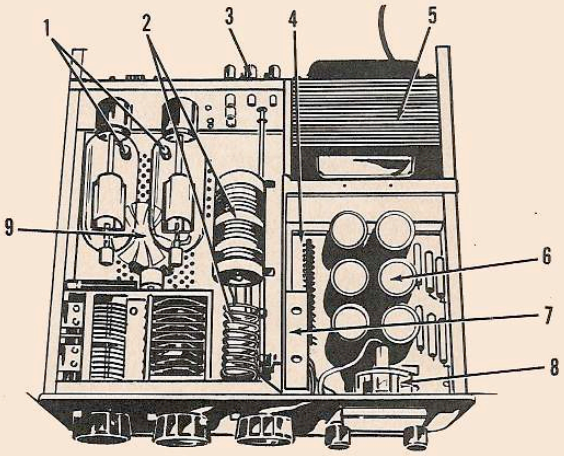
Well-constructed throughout, the SB-200 features a heavy-gauge one-piece aluminum chassis, partitioned for extra strength and isolation of circuits, and a clean circuit layout for a compact, yet lightweight unit that can be used anywhere. The power supply is designed for operation on either 120 volt or 240 volt power sources.

Designed for complete operating versatility the SB-200 is an ideal companion for the SB-400 Transmitter, the soon to be released SB-100 Transceiver, and nearly all other popular SSB & CW exciters in use today! When you go "high-power" . . . choose the SB-200 for extra value, performance and dependability!

Kit SB-200, 42 lbs. . . . $20 dn., $17 mo. $200.00

SB-200 SPECIFICATIONS—Band coverage: 80, 40, 20, 15 & 10 meters. **Maximum power input:** 1200 watts P.E.P. SSB, 1000 watts CW. **Driving power required:** 70 to 100 watts, depending upon frequency. **Duty cycle:** SSB, continuous voice modulation; CW, 50% (key down time not to exceed 5 min.). **Third order distortion:** 30 db or better at 1000 watts P.E.P. **Output impedance:** 50 to 75 ohm unbalanced; variable pi-output circuit. SWR not to exceed 2:1. **Input impedance:** 52 ohm unbalanced; broad-band pretuned input circuit requires no tuning. **Meter functions:** 0-100 ma grid current, 0-1000 ma plate current, 0-1000 relative power, 1:1 to 3:1 SWR, 1500 to 3000 volts high voltage. **Front panel controls:** Load; Tune; Band; Relative Power Sensitivity; Meter Switch, Grid-Plate-Rel. Power-SWR-HV; and Power Switch, on/off. **Tube complement:** Two 572B/T-160-L (in parallel). **Power requirements:** 120 volts AC @ 16 amperes (max.), 240 volts AC @ 8 amperes (max.). **Cabinet size:** 14⅞" W x 6⅝" H x 13⅜" D. **Net weight:** 35 lbs.

TOP QUALITY CONSERVATIVELY-RATED COMPONENTS ARE USED THROUGHOUT THE DESIGN OF THE SB-200 TO ASSURE EXTRA YEARS OF DEPENDABLE, TROUBLE-FREE PERFORMANCE.



1. Two heavy-duty 572B/T-160-L tubes in parallel
2. Separate pi-network output coils for 80-20 meters & 15-10 meters
3. Pretuned cathode input circuits
4. Long-life silicon high-voltage rectifiers
5. Conservatively rated 120/240 volt power transformer
6. High capacity (125 mfd ea.) voltage-doubler filter capacitors
7. Two manual-reset circuit breakers for power supply protection
8. Switched panel meter measures SWR, Rel. Pwr., plate current, grid current, & hi-voltage
9. Fan-cooled final amplifier compartment for long tube life

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Figure 4: Heathkit Introduces the SB-200 Kilowatt Linear Amplifier
Heathkit Catalog 800/47 - July 1964

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