fast ppliesammable power su

The expanded bandwidth of power supplies with fast-programming capabilities, compared to conventional power supplies, is achieved by circuit changes including the removal of output and feedback capacitors which serve as gain-roll-off networks and restabilizing the control loop by means of lag networks. This section lists high voltage "OPS" models and bipolar "BOP" models which are exclusively wide band power amplifiers.

A different class of fast programmable power supply are the "ATE" and "BHK" series, listed elsewhere in this catalog. These models have the unique ability to be user-configured for either fast-programmable or conventional operation. When configured for fast-programable operation, the comments below are applicable.

The ability to respond to fast control signals is accompanied by several constraints which must be fully appreciated by potential users of fast programmable power supplies.

1. There is some increase in the *unprogrammed output deviation specification* (ripple and noise). To minimize this increase, the construction of fast programmable units is distinguished from conventional power supplies by a greater emphasis on shielding and component placement to minimize noise pickup. In actual applications, such power supplies require greater attention to such details as ground loop avoidance, shielding, use of twisted pairs, wire routing, etc.
2. A conventional power supply responds slowly to input signals and its dynamic stability is governed by the large output capacitor. As a result, its unity gain crossover frequency is at a very low frequency and the phase margin (a measure of stability) is very large. A conventional power supply therefore represents a very stable closed-loop system even with reactive loads, since any additional phase-shift introduced by the load is at a frequency far away from the unity gain crossover frequency (See Fig. 1).

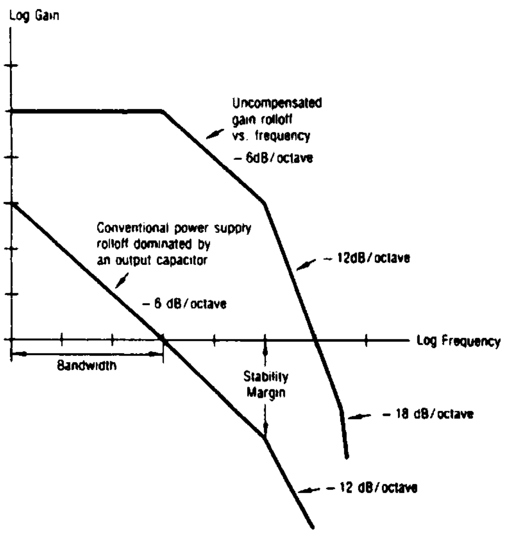

Figure 1: Gain-frequency plot, conventional power supply showing narrow bandwidth, large stability margin

3. Fast programmable power supplies and convertible models in their fast-programmable mode are far less tolerant of load reactance. Since bandwidth has been vastly increased, the unity gain crossover frequency lies at a much higher frequency and therefore the stability margin has correspondingly decreased (See Fig. 2).

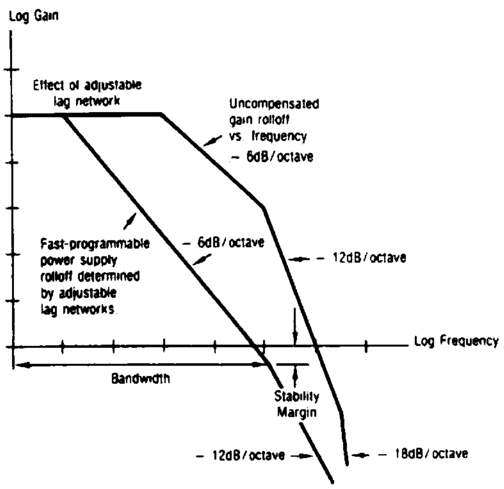

Figure 2: Gain-frequency plot, fast programmable power supply showing increased bandwidth, and reduced stability margin

A fast programmable power supply, although stable with resistive loads, may become unstable with reactive loads. The reason is the additional phase-shift introduced by a reactive load at its output. This may shift the power supply's response curve precariously close to the unity gain crossover frequency and thereby reduce the stability margin. As a result, the power supply may, with reactive loads, exhibit instability or even oscillatory behavior. For stable operation of a fast programmable power supply, the reactive load characteristics must be

A major part of the specifications for the various fast programmable models is devoted (as might be expected) to *dynamics*.

Under this heading there are specifications for:

- The maximum slewing rate.
- Programming time constant.
- Frequency response.
- Voltage recovery for step-load current.
- Current recovery for step-load voltage.
- Output impedance (versus frequency).

These specifications are designed to give a profile of the responses to various dynamic stimuli in both the time and frequency domains.

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BOP™

bipolar operational voltage stabilizer

The Bipolar Operational Power Supply, combines the capabilities of fast-programmable power supplies, like the ATE, with a bidirectional complementary-symmetry output stage that can respond in either direction from zero. The BOP is; in effect, a large, d-c coupled, inverting power amplifier. It is made in a bench/system-rack form with a single control-channel equipped with a patch-board panel for easy access to the control functions.

MODEL TABLE

MODEL	d-c OUTPUT RANGE VOLTS	d-c OUTPUT RANGE AMPS.	CURRENT SINK	OUTPUT IMPEDANCE VOLTAGE MODE SERIES R	OUTPUT IMPEDANCE VOLTAGE MODE SERIES L	OUTPUT IMPEDANCE CURRENT MODE[1] SHUNT R	OUTPUT IMPEDANCE CURRENT MODE[1] SHUNT C	a-c SOURCE CURRENT at 125V a-c	SIZE	SHIP WGT lbs.	SHIP WGT kg.
BOP 15-20M	+15 to −15	+20 to −20	±4A	0.2 mΩ	25 μH	1750 Ω	10.0 μF	8.0A	C	94	42.7
BOP 36-1.5M	+36 to −36	+1.5 to −1.5	±0.3A	5 mΩ	10 μH	23 kΩ	0.22 μF	1.6A	A	27	12.3
BOP 36-5M	+36 to −36	+5 to −5	±1A	1.5 mΩ	15 μH	7 kΩ	0.75 μF	4.6A	B	52	23.6
BOP 72-1.5M	+72 to −72	+1.5 to −1.5	±0.3A	10 mΩ	20 μH	23 kΩ	0.17 μF	3.2A	C	64	29.1
BOP 72-5M	+72 to −72	+5 to −5	±1A	3 mΩ	30 μH	7 kΩ	0.56 μF	9.2A	C	94	42.7

[1]External current sensing using a 1-volt current sensing sample.

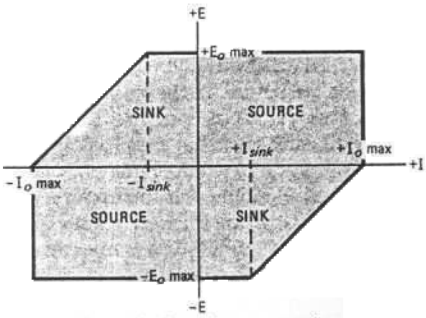

Figure 1: 4-quadrant operation.

STATIC SPECIFICATIONS

INFLUENCE QUANTITY		AMPLIFIER OFFSETS VOLTAGE ΔE_{io}	AMPLIFIER OFFSETS CURRENT ΔI_{io}	REFERENCES 6.2V ± 5%
SOURCE VOLTAGE (min.-max.).		<0.1 mV	<10 nA	0.0005%
LOAD (No load—full load):		<1.0 mV	<10 nA	—
TIME (8-hour drift):		<0.1 mV	<50 nA	0.005%
TEMPERATURE, Per °C:		<0.08 mV	<50 nA	0.005%
RIPPLE and NOISE:[3]	rms	<0.01% of E_O — or 3 mV[2]		—
	p-p[4]	<0.05% of E_O — or 15 mV[2]		—

[2]Whichever is greater.
[3]One terminal must be grounded, or connected so that the common mode current does not flow through the load or, in current mode, through the current- sensing resistor.
[4]Peak-to-peak ripple is measured over a 20 Hz to 10 MHz bandwidth.

VOLTAGE CONTROL CHANNEL

OUTPUT RANGE: The unique character of the BOP, its ability to operate with either positive or negative output, bidirectionally, as a source, is enhanced by its ability to function as a limited *sink*. BOP is a "*sink*" when the polarity of its voltage does not agree with the direction of its current—it absorbs energy.

If voltage and current are plotted orthogonally, as in Figure 1, quadrants I and III are the source quadrants, II and IV are sink quadrants. The operating region of a BOP is defined by the shaded portion of the output characteristic.

CONTROL/PROGRAMMING: BOP models have a front panel patch board with a built-in vernier voltage feedback rheostat and bipolar reference. Output voltage is controlled by controlling the reference potentiometer from the plus (+) to the minus (−) reference through zero. The output voltage is proportioned to the selected reference by the feedback rheostat. The patch board construction makes it easy to sum or substitute other potentials at the input and to substitute external feedback to stabilize current or such physical phenomena as heat, speed, force, or electrochemical action.

OFFSETS: The equivalent offset voltage and current variations for BOP are tabulated for the effect of source changes, load, temperature, and time. Calculate their effect on the output by the relationship:

$$\Delta E_o = \pm \Delta E_r (R_f/R_i) \pm \Delta E_{io} (1 + R_f/R_i) \pm \Delta I_{io} (R_f)$$

where R_f is the feedback rheostat and R_i is the input resistor from the reference, E_r.

OFFSET NULLING: The initial or bias part of the main control channel's voltage offset (E_{io}) and current offset (I_{io}) can be nulled (zeroed) by built-in trimmers.

REFERENCES: A pair of ±6.2V ±5%, 1 milliampere references referred to the common/sense terminal are provided for offsetting or biasing purposes.

GAIN: The open-loop d-c gain is in excess of 35,000 volts/volt.

CURRENT STABILIZATION

The BOP is equipped with a pair of built-in current-sensing and feedback arrangements for protective limiting. They are set for approximately 110% of the rated current in both directions and are not adjustable.

For the precision control of current, bidirectionally, the feedback to the main control channel can be reconfigured so as to sample the drop across an external current-sensing resistor in the common output lead.

DYNAMICS

Each BOP is equipped with an internal, fast/slow selector switch. The slow position restricts the bandwidth so that the BOP can drive reactive loads without restriction. The slow position is recommended for low frequency or d-c application to discrimminate against higher frequency pick-up noise.

OUTPUT IMPEDANCE: Expressed as a function of frequency, the output impedance is a measure of dynamic stabilization. As a voltage stabilizer, the d-c and low frequency value is given by the load effect. At frequencies above the stabilizer's cutoff, the impedance increase with frequency becomes asymptotic to the tabulated characteristic series inductance. As a current stabilizer, the impedance decrease above the stabilizer's cutoff frequency becomes asymptotic to the tabulated characteristic shunt capacitance. The table gives these values for each BOP model.

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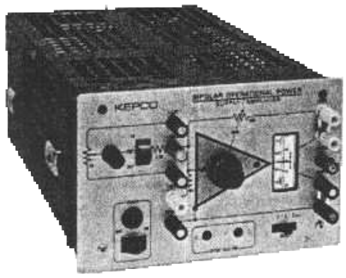
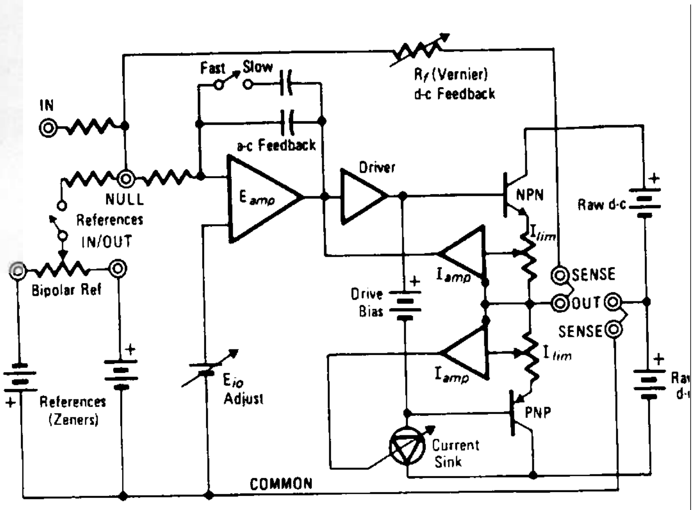
Model BOP 15-20M
(Size C-"full-rack")



Model BOP 36-1.5M
(Size A-"half-rack")

SIMPLIFIED SCHEMATIC DIAGRAM



DISTORTION: For a small signal (2 volts peak-to-peak, no load), harmonic distortion is less than 0.5%.

BANDWIDTH/PROGRAMMING SPEED: The dynamics of the BOP output may be expressed in both the time domain (as its response to a step-program) or in the frequency domain (bandwidth for large and small signals). These figures are tabulated below.

DYNAMIC SPECIFICATION	MODE SWITCH	BOP 15-20M	BOP 36-1.5M	BOP 36-5M	BOP 72-1.5M	BOP 72-5M
BANDWIDTH (d-c to f_{-3dB})	FAST	13 kHz	13 kHz	13 kHz	13 kHz	13 kHz
	SLOW	0.6 kHz	1 kHz	1 kHz	1 kHz	1 kHz
PROGRAMMING TIME CONSTANT*	FAST	12 µsec.	12 µsec.	12 µsec.	12 µsec.	12 µsec.
	SLOW	250 µsec.	150 µsec.	150 µsec.	150 µsec.	150 µsec.
LARGE SIGNAL FREQUENCY RESPONSE	FAST	25 kHz	20 kHz	20 kHz	20 kHz	20 kHz
	SLOW	1 kHz	3 kHz	3 kHz	2 kHz	2 kHz
SLEWING RATE	FAST	2V/µsec.	4.8V/µsec.	4.8V/µsec.	9V/µsec.	9V/µsec.
	SLOW	0.1V/µsec.	0.7V/µsec.	0.7V/µsec.	0.9V/µsec.	0.9V/µsec.
TRANSIENT RECOVERY (Step Load Change) Voltage	FAST	50 µsec.	50 µsec.	50 µsec.	50 µsec.	50 µsec.
	SLOW	500 µsec.	500 µsec.	500 µsec.	500 µsec.	500 µsec.
Current	FAST	50 µsec.	50 µsec.	50 µsec.	50 µsec.	50 µsec.
	SLOW	1 msec.	500 µsec.	500 µsec.	500 µsec.	500 µsec.

*Input feedback set for gain = 10.

STABILITY & LOAD REACTANCE: The BOP power supply behaves like a wideband amplifier, or, as a 1st order (single breakpoint) closed loop feedback system. The phase-gain versus frequency characteristic is determined by the f_{-3dB} breakpoint (corner) frequency, as indicated in the dynamic specification table. The closed loop gain is given by: $\frac{E_0 \text{ (setting)}}{6}$.

The unity gain crossover frequency, with 90° phase margin, is a relatively high frequency, and the power supply, although stable with a resistive load, may become unstable and even oscillate into reactive loads. The additional phase shift, created by a reactive load (RC in voltage mode and L/R in current mode) with a breakpoint approaching the unity gain crossover frequency, will cause the BOP's dynamic response to exhibit a peak and even sustain oscillation. If the load's breakpoint is at a frequency much below the BOP's, the power supply will be stable, but the frequency response will be governed by the load's time constant.

GENERAL

SERIES/PARALLEL: Units may be connected in series for added voltage, using a master/slave interconnection. They cannot be used in parallel.

ISOLATION FROM GROUND: The circuit and output terminals of BOP have no d-c connection to ground, and may be floated up to 500 volts (d-c or peak) off ground. The common mode current from output to ground is less than 5 microamperes rms, 50 microamperes, peak-to-peak at 115V a-c, 60 Hz.

SOURCE POWER REQUIREMENTS: Units are factory-wired for 105–125V a-c, 50–65 Hz power. A simple jumper change will reconfigure the input for 210–250V a-c, 50–65 Hz. The two ±36V BOP models (in a half-rack package) are protected by a fuse. The two ±72V models and the ±15V unit (in the full-rack size) are protected by a circuit breaker. All models incorporate a "low-source" voltage monitor which trips an internal clamp at turn-off (precluding overshoot). A timing circuit delays reapplication of source power for approximately 2 seconds.

TEMPERATURE RATINGS:

Storage: −40°C to +85°C.

Operating: −20°C to +65°C. Cooling is by built-in, sealed-bearing blowers exhausting to the rear. Full output current is delivered at +65°C. No derating, or external heat sink is required.

STANDARDS: BOP models are designed and tested in accordance with NEMA standard PY-1-1972 and IEC recommendation 478 (parts 1-4).

TERMINALS: BOP models are equipped with a 10-terminal patch board providing convenient access to the signal input, output, feedback, and reference points. The front panel connections are duplicated on a rear-mounted barrier-strip.

METERS: Half-rack models use a single 2-inch recessed meter for reading d-c volts and amperes and a-c (rms) volts. Accuracy is ±3%. The full-rack models have independent 3-inch recessed meters with ±2% accuracy.

MOUNTING: The "full-rack" sized models have accessory flanges for direct installation in standard 19-inch racks. Half-rack sized models may be mounted in RA-24 rack adapter.

DIMENSIONS: (English in inches, metric in mm.)
See dimensional drawings.

English Measure:

Size A: 5 7/32H x 8 11/32W x 12 7/8D*
Size B: 5 7/32H x 8 11/32W x 17 3/8D*
Size C: 5 7/32H x 16 1/2W** x 17 1/64D*

Metric Measure:

Size A: 132.6 H x 211.9 W x 327.0 D*
Size B: 132.6 H x 211.9 W x 441.3 D*
Size C: 132.6 H x 419.1 W** x 432.2 D*

*behind panel.
**with "ears" standard 19" panel width.

FINISH: *Panel:* Light gray color 26440, Fed. Std. 595.
Case: Charcoal gray texture.

Special terms used in these specifications are defined in the glossary section.

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