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Current stabilization made easy

Electronic equipment and systems designed for mobile use require a stable operating point over a wide temperature range. At the same time, they must work at low operating voltages with low power consumption. The Semiconductor Group has specially developed the BCR 400 active operating point stabilizer for these applications.

Cellphones, automotive electronics systems, and portables in entertainment electronics are classic examples of mobile equipment. Common to them all is the demand for low supply voltages, low power consumption and constant operating points, even at greatly varying temperatures. What's more, they must all be housed in a minimum of space. Conventional stabilization circuits based on negative feedback in series or parallel often produce unacceptable fluctuations in the operating current as a result of both voltage fluctuations and the range of current gain of the transistor used. To optimize these circuits, extra components are needed, which take up more board space – and consume even more power. The Semiconductor Group has applied its know-how in the design of transistors with integrated resistors (digital transistors) to develop the BCR 400 as an active operating point stabilizer on a single chip. Typical applications are the RF stages of cellphones or cordless phones and high-precision timers in control circuits (**Fig. 1**).

Mode of operation

Operation of the BCR 400 is illustrated by the specimen circuit for collector current stabilization (**Fig. 1a**) in conjunction with the internal circuit diagram (**Fig. 2**). The collector current I_C of the npn RF transistor to be controlled, together with the emitter current $I_{E(pnp)}$ through the total resistance R_{tot} of the parallel resistors R_{int} and R_{ext}, generates a voltage drop V (I). This determines the emitter potential of the pnp transistor in the BCR 400, whose collector supplies the base of the transistor to be controlled. A reference voltage V_{ref} is derived via the two diodes and defines the base potential of the pnp transistor. When current is flowing, the emitter-base voltage $V_{EB(pnp)}$ is about 0.65 V, the reference voltage V_{ref} about 1.3 V. The voltage drop V (I) is thus fixed at about 0.65 V within the operating range.

The emitter current $I_{E(pnp)}$ is approximately equal to the base current $I_{B(npn)}$ of the transistor to be controlled, which can be neglected if the current gain B_{npn} is more than 40 with regard to the collector current $I_{C(pnp)}$. The following approximate relationships thus apply:

$I_{C(npn)} = 0.65\ \mathrm{V}/R_{tot}$

and

$V_{CE(npn)} = V - 0.65\ \mathrm{V}$

Control characteristics

Fluctuations in operating voltage

As the operating voltage V rises, the current through the reference diodes also rises, but the reference voltage V_{ref} remains approximately the same as a result of the exponential diode characteristic. The voltage drop V (I) hardly changes either, and the collector current I_C also remains approximately constant, but the collector-emitter voltages V_{CE} of both transistors rise directly with V.

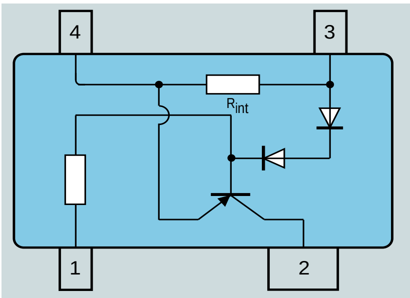
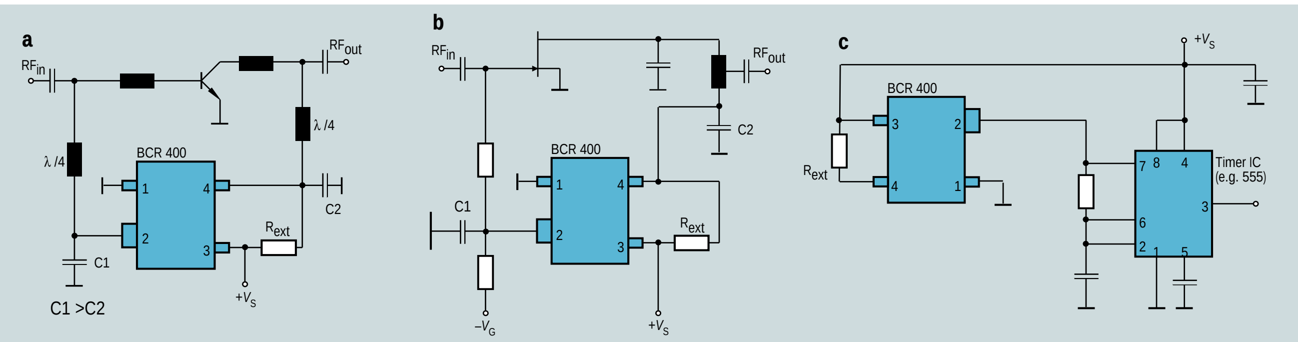


Fig. 2 Internal circuitry of the BCR 400

Fig. 1 The BCR 400 has been specially designed for mobile applications. a Collector current stabilization of an RF transistor, e.g. SIEGET BFP 405 b Drain current stabilization with additional negative voltage to control a GaAs FET c Precision timer circuit to control the capacitor charge



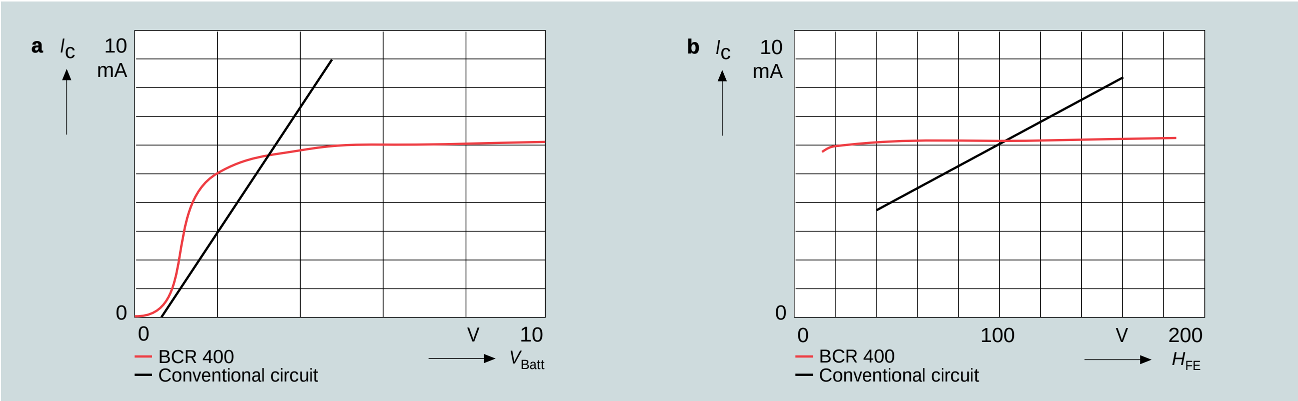


Fig. 3 The BCR 400 is significantly more effective than conventional circuits in controlling fluctuations of both the operating voltage (a) and the current gain of the transistor to be stabilized (b)

Parameter scatter of the transistor to be controlled

The parameter scatter of the transistor to be controlled affects first and foremost its current gain B. The values of the mesh determining current hardly change at all as a result. Smaller or greater values of B merely change the value of $I_{E(pnp)}$, which is in any case small compared with $I_{C(pnp)}$. Even in the extreme case of a current gain B_{npn} of 10, this would merely reduce the value of I_C by about 10%.

Temperature fluctuations

Temperature fluctuations lead on the one hand to massive changes in B, but this is largely without consequence, as mentioned above. On the other hand, the forward voltages at the pn junctions change by a few millivolts, the effect of one of the diodes being compensated by that of $V_{EB(pnp)}$, so that the temperature coefficient of only one diode has to be considered. This has a value of around –2 mV/K and consequently leads to a maximum V(I) error (and thus an IC error as well) of ±15% for a temperature fluctuation of ± 50 K. The fluctuation of $V_{EB(npn)}$ has no effect, as it does not influence the mesh determining current.

Fig. 3 depicts the control characteristics of the BCR 400. It is very much more effective than conventional circuits in stabilizing fluctuations in both the operating voltage and the current gain of the transistor to be controlled.

Key data

Table 1 lists the limit data and characteristic values of the BCR 400. The low voltage drop of only 0.7 V at an operating range from < 200 µA to > 200 mA deserves special mention.

The BCR 400 will be available from mid-1996 as an SMD in two versions:

- the BCR 400 R in the SOT-143 package (same dimensions as the SOT-23), and
- the BCR 400 W in the mini-SMD package SOT-343 (same dimensions as the SOT-323).

Both versions are pin-compatible and supplied on 8 mm belts containing 3000 SMDs. ☐

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Table 1 Limit data and characteristic values of the BCR 400

Limit data		
Operating voltage (final version)	V_s	15 V
Control current	I_{contr}	10 mA
Control voltage	V_{contr}	8 V
Characteristic values		
Additional current consumption (V_s = 3 V)	I_O	max. 40 µA
Minimum stabilized current (V_s = 3 V)	I_{min}	0.1 mA
Change in collector current with	$\Delta I_c / I_c$	
– temperature fluctuations		0.2% / K
– fluctuations in operating voltage (V_s > 3 V)		0.15 $\Delta V_s/V_s$

Margarete Deckers, Dipl.-Phys.,
studied physics at RWTH Aachen, specializing in solid-state physics. Since 1985, Mrs. Deckers (35) has been responsible for product development of AF transistors and diodes in the Semiconductor Group of Siemens AG.

Lothar Musiol, Dipl.-Ing. (FH),
studied telecommunications at Munich Polytechnic and joined the Siemens Semiconductor Group in 1983. Mr. Musiol (36) is now involved in applications engineering for various silicon RF components and is responsible for the instruments and software necessary to characterize them in development.

Achim Renner, Dipl.-Ing.,
studied photographic engineering in Cologne. In 1986, he joined the Semiconductor Group, where he spent three years as a process engineer working on bipolar and MOS wafer fabrication. He was then employed as a product engineer for 1M and 4M memories in Perlach and Regensburg. Since 1991, Mr. Renner (36) has been involved in marketing AF components in the Discrete Semiconductor Division.