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Bandgap voltage reference

Basics of electronic circuits Opamp principle of operation Bipolar Junction Transistor Basics Many circuits, including voltage regulators, analog-digital and digital-analog converters, require a voltage reference that is as precise as possible. Their precision depends on it. This means that the voltage reference would ideally be PVT-independent: P: Manufacturing process variations V: Supply voltage T: Temperature bandgap reference circuits cancel two opposing temperature deviations. That is, if we have two references, one generating voltage $V_1 with demea value Frac and part V_1 = alpha and the other with $V_2 with temperature coefficients frac V_2 - partial T = -alpha V_1 $V + V_2 generates a temperature-independent voltage: frac (partially V_ and -off) = frac Partial V_1 + part T + frac-part-V_2 = alpha = 0 to delete them, the temperature coefficients must have opposite characters, a negative (NTC) and a positive (PTC). A Bipolar Junction Transistor (BJT) can provide both the NTC and PTC voltages. So let's check the BJT a little bit. What you should know about the BJT The BJT collector current is defined as: $I_c = I_Se V_, V_t, where $V_be is the base emitter voltage. $V_t = kT/q is the thermal voltage that is practically insensitive to process fluctuations and is defined by the Boltzmann constant $k, the charge of an electron $q and the temperature $T. $I_S is a process- and temperature-dependent parameter: $I_S = I_0 e-frac-V_-G0-V_t-V_t-V_t - $I_0 = I_S e-frac-V_-G0-V_t- and $I_0 is a device parameter and $V_ It is the tape gap voltage of silicon, the energy necessary to release an electron from the outer shell of the silicon. The band gap itself is temperature dependent, so that $V_-G0- is extrapolated from 300oK to 0oK $V. It has the theoretical value of 1.205V. The collector current can also be off. $I_c = I_0e V_ - G0 - V_,-,Vt, which simplifies the relationship to the band gap voltage. Create the NTC voltage The negative temperature coefficient is generated by a PN node. The bipolar junction transistor (BJT) base emitter crossing is a common PN cross used in bandgap references. With the collector current of the BJT is the base emitter voltage: $V_ =V_G0 - frackT q log frac I_0, I_c So, how does $V depend on the temperature? Assuming that $I_c- does not depend on temperature: frac V_-part-T- = --frac-k-log protocol frac I_0, I_c, since $I_0- is much larger than $I_c, the term log is not strongly influenced by the BJT current. Normally, the temperature coefficient is about 2mV: The positive temperature coefficient is generated by the thermal voltage $V_t. Suppose we take the difference between two base emitter nodes of BJTs: $V_be1 - V_-be2 = V_t log protocol I_ I_,S1- - V_t log-I_-I_-S 2 - Delta V_ = V_t logc I_,c1, I_ I_, I_, I_, I_, S1 Simple enough, delta-V_- and -t $V- But still... we want the tension to be mass, so we need to work out a bit more. Let's find the voltages over the two resistors $V_R1 = V_B - V_-be2 - (V_B - V_'be1') = V_'be1' - V_'be2' = 'Delta V_'be' $V_R2 = R_2-cdot-2I_c = R_2 cdot 2 V_,R1 R_1 = 2.2, R_2 V_ $V V_ R_1 We can also replace the $V that are called : $V_-R2 = 2.$V-R_2 R2-R_1-R_1-V_t log protocol frac-I_-c-I_-S2-I_c I_-S1-I_c I_-S1-% = 2-frac-% = 2-frac-% R_2-R_1-V_t protocol,-I_-S2-S2-S2-S2-S2-S2-S2-S2-S2-S2-S2-S2-S2-S1-S1-S1-S1-S1-, V_t -I_-S I_2-S2-S2-S2 $q-s-s2-s2-s$k KV_t 1- = 2-frac-R_2-R_1-R_1-$V_t- is only proportional to the temperature, with the temperature coefficient: Frac V_t , Part-T , approx. +0.085mV/oC. The thing is, the terms $I_S are proportional to the surface of the transistor and very similar for nearby transistors (in terms of layout). Therefore, the following is quite accurate: fracI_,S2, I_, S1, A_2, A_1, where $A is the area of the transistor. Then: $V_R2= 2-Frac-R_2-R_1-Log-Log-Protocol fracA_2, A_1 V_t A_1. it is strange that $V_B' is already the sum of a voltage proportional to $V_t(PTC) and a $V (NTC): $V_B = V_R2 + V_be1 = 2.2, frac R_2, R_1, A_1 A_2 R_1, R_1, V_t $V V_ , summary of NTC and PTC voltages So our main idea is to create two voltages, a PTC, The diagram would look something like this: The sum of the two voltages would be: $V_ + KV_t = V_G0 - frackT -q ,frac'I_0' , I_c ' + K'frac'kT' = V_ I_c I_0 As we have seen when creating the PTC voltage, $K will probably come from a ratio of resistors and/or ranges of transistors, and with a value of 2/0,085, approx. 23,085, approx. 23,5. Note that after the temperature-dependent conditions $V on the bandgap after the temperature-dependent conditions $V _ If you ever see a voltage reference with a value close to 1.2V, it comes from here! The next obvious question is: How do we do this with real circuits? There are several options, but the main recipe is the following: Generate two streams to bias two different BJTs Create a branch with two BJTs and a resistor (or equivalent resistance) Find a path that adds a PTC and NTC Voltages Optimize the size of the transistors and/or resistors to add the correct $K or the circuit can stabilize at zero current if examples Widlar bandgap The output is: . V_ ' out' = I_2 R_2 + V_'be3' From the lower branch: '$V_'be1' = V_'be2' + I_2R_3 '$I_2 = 'frac'V_'be1' - V_'be R_3 2' Delta V_ expression: $I_2 = $I_2 = $I_2 = frac-V_t-R_3-log-,left-ProtokollV_ I_2I_ I_1I_ () = fracR_2 R_3 V_t,log) ('frac'I_1I_'S1','I_2I_'S2''right) + V_'be3'' The circuit is so large that $I_1=I_2. what to : V_ - off = fracR_2, R_3 V_tloglinks (fracI_S1I_S2-Right) + V_-be3-B-Bandgap The output is: V_ = V_,be1 + 2I_c R_1. Since they are equal, the same current must flow through them and converge in $R_1. From the middle branch: '$V_'be1' = V_'be2' + I_cR_2' '$I_c' = 'frac'V_'be1' - V_'be2'R_2' From the expression ''Delta V_'be'I_cI_ I_cI_ R_2 V_t $I'V_ I_ I_ V_t R_2 R_1 $V For PNP transistors the output is: $V_ = V_eb2 + V_ V_ we have: $V__eb1 = V_R2 + V_-V (V_ V_ and $V V_ I_2 $I R_2 V_ V_ - what the Delta V_eb: $V_R2 = V_t-Log-Links-File ('frac'I_1I_'S1''I_2I_'S2'right'' ' V_t'log'left'$V I_ I_'R_2 V_ V_t,frac I_S1 I_, s2, Right) - Some thoughts on other dependencies process variations As already mentioned, the stress reference should also not react to process deviations. This is usually done by making the output dependent on a ratio of values (resistance pair, BJTs pair, etc.). When displaying these devices, their values are very similar during manufacture and depend very similarly on other parameters, such as.B. temperature. As you can see, winning $K b in all bandgap references is one such case. Power supply If you need a precision voltage reference, does it mean you don't have one yet, right? The power supply of the reference is therefore not accurate, and the reference should be insensitive to it. The way to solve this is through differential circuits. In the Bandgap examples, a change in power would affect the currents of both branches equally. Therefore, the assumption of the same currents would still hold and the effects of power supply fluctuations would abort at the output voltage. Temperature Not all temperature-dependent effects can still be For example: temperature changes resistance values, resistance changes collector current and collector current changes the sensitivity of $V_be, to the temperature slightly temperature changes the offset voltage of the opamp, which in turn changes the voltages over the transistors/resistors and balances the collector current of both transistors. References If I have helped you in any way, please help me back by liking this website at the bottom of the page or by clicking on the link below. It would mean the world to me! Reference voltage independent of temperature A Bandgap voltage reference is a temperature-independent voltage reference circuit that is widely used in integrated circuits. It generates a fixed (constant) voltage independent of power supply fluctuations, temperature changes and circuit load from one device. It usually has an output voltage of 1.25 V (near the theoretical 1.22 eV (0.195 aJ) band gap of silicon at 0 K). This circuit concept was first published by David Hilbiber in 1964. [1] Bob Widlar,[2] Paul Brokaw[3] and others[4] followed other commercially successful versions. Switching of a Brokaw bandgap reference Characteristic and balancing point of T1 and T2 The voltage difference between two p-n nodes (e.B. diodes) operated with different current densities is used to generate a current proportional to the absolute temperature (PTAT) in a resistance. This current is used to generate a voltage in a second resistor. This voltage, in turn, is added to the voltage of one of the nodes (or a third, in some implementations). The voltage via a diode that is operated with constant current complements the absolute temperature (CTAT) with a temperature coefficient of approx. 2 mV/K. If the ratio between the first and second resistance is correctly selected, the first-order effects of the diode's temperature dependence and PTAT current are eliminated. The resulting voltage is approximately 1.2-1.3 V, depending on the technology and circuit design, and is close to the theoretical 1.22 eV bandwidth of silicon at 0 K. The remaining voltage change over the operating temperature of typical integrated circuits is in the order of a few millivolts. This temperature dependence has a typical parabolic residual behavior, since the linear (first order) effects are selected for aborting. Because the output voltage for typical bandgap reference circuits is set by 1.25 V by definition, the minimum operating voltage is about 1.4 V because in a CMOS circuit at least one flow source voltage of a field effect transistor (FET) must be added. As a result, recent work focuses on the for alternative solutions, in which e.B currents are added instead of voltages, resulting in a lower theoretical limit for the operating voltage. [4] The first letter of the acronym CTAT is sometimes constant and non-complementary. The term , constant with temperature (CWT), exists to correct this confusion, but is not widely used. When a PTAT and a CTAT current are summarized, only the linear current conditions are compensated, while the higher-value conditions limit the temperature drift (TD) of the bandgap reference to about 20 ppm/°C over a temperature range of 100 °C. For this reason, Malcovati [5] designed a circuit topology in 2001 that can compensate for high-level nonlinearities for improved TD. This design used an improved version of the Banba [4] topology and an analysis of the base emitter temperature effects performed by Tsividis in 1980. [6] In 2012, Andreou[7][8] has the nonlinear compensation of high order by using a second Op. Amp. further improved with an additional resistance leg at the point where the two currents are combined. This method further improved curvature correction and achieved superior TD performance over a wider temperature range. In addition, improved line regulation and less noise was achieved. The other important problem in the design of bandgap references is the energy efficiency and the size of the circuit. Since a bandgap reference is typically based on BJT devices and resistors, the overall size of the circuit could be large and therefore expensive for the IC design. In addition, this type of circuit can consume a lot of energy to achieve the desired noise and precision specification. [9] Despite these limitations, the Bandgap voltage reference is often used in voltage regulators and covers most 78xx and 79xx devices together with the LM317, LM337, and TL431 devices. Temperature coefficients of up to 1.5 to 2.0 ppm/°C can be achieved with bandgap references. [a] However, the parabolic property of voltage versus temperature means that a single number in ppm/°C does not adequately describe the behavior of the circuit. Manufacturers' data sheets show that the temperature at which the peak (or trough) of the stress curve occurs is subject to normal sampling fluctuations in production. Bandgaps are also suitable for low-power applications. [b] Patents 1966, US patent 3271660, reference voltage source, David Hilbiber. [10] 1971, US patent 3617859, electric controller with zero-temperature coefficient voltage reference circuit, Robert Dobkin and Robert Widlar. [11] 1981, US Patent 4249122, Temperature Compensated Bandgap IC Voltage References, Robert Widlar. [12] 1984, US Patent 4447784, Temperature-compensated Bandgap Voltage Reference Circuit, Robert Dobkin. [13] Notes - For example, LT6657 from Linear Technology and ADR4550 from Analog Devices. • For example, A cathode current with the Maxim Integrated MAX6009 Shunt voltage reference. See also Brokaw Bandgap Reference LM317 Silicon Bandgap Temperature Sensor References ,

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