March 2021

HIGH VOLTAGE OPERATIONAL TRANSCONDUCTIVE AMPLIFIER (OTA) DESIGN FOR A CONTROL LOOP

Jan Sundermeyer

Daniel Micusik

Juergen Hauenschild

Sachidanandam Sundarraju

HIGH VOLTAGE OPERATIONAL TRANSCONDUCTIVE AMPLIFIER (OTA) DESIGN FOR A CONTROL LOOP

AUTHORS:
Jan Sundermeyer
Daniel Micusik
Juergen Hauenschild
Sachidanandam Sundarraju

ABSTRACT

An operational transconductance amplifier (OTA) is typically used in the optical transmitter for an analog control. Additionally, for an OTA, the input range may be shifted to the output range and the output range is to be limited to safely operate a cascode/drive transistor. OTA operation is linear and is not digitally switched. Presented herein is an OTA design that can operate with a power supply voltage greater than the drain-source voltage (VDS) breakdown voltage. The output range can be limited to the gate-source voltage (VGS) breakdown range and can be adapted to a desired range using a cascode transistor. Additionally, the OTA design presented herein can operate safely in non-switched applications.

DETAILED DESCRIPTION

A folded cascode OTA design can be optimized to handle a large input and output signal range. For high voltage operations where the supply voltage exceeds the transistor break down voltage, the output signal range needs to be shifted and limited in range to allow safe operation of the circuit. The targeted shift and limit of the output range distinguishes this approach from typical OTAs. This reduces the need for extra voltage domains, which increases the cost for external components, printed circuit board (PCB) routing, and chip size because additional chip connectors (bumps) are needed.

Figure 1, below, illustrates a general folded cascade OTA design involving a P-channel metal-oxide-semiconductor (PMOS) input stage, however, the design also works with an N-channel MOS (NMOS) input stage with minor adaptations. The folded cascode OTA can also be made with bipolar transistors, though the use of bipolar transistors less common. A common approach involving bipolar transistors is to operate the folded cascode OTA in a low voltage domain and then shift the signal to the desired range, which complicates the circuitry as more voltage domains are necessary.

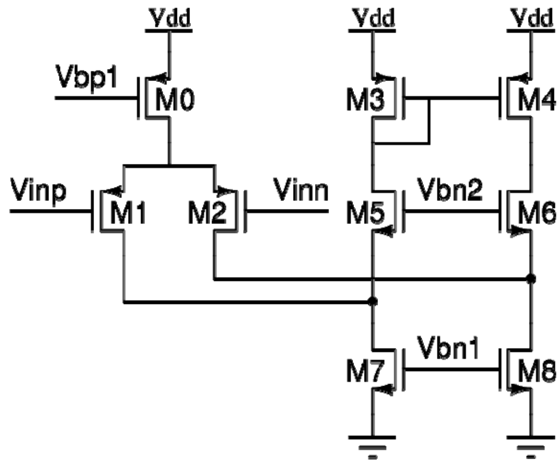

Figure 1: General Folded Cascode OTA Design

This proposal provides a folded OTA design, as shown in Figure 2, below, that utilizes a current mirror in order to adjust the output signal range to a desired voltage span. An additional pair of cascade transistors are added (M9/M10, as shown in Figure 2) that impose a lower limit on an output signal with help of Vbn3. M11 as shown in the design of Figure 2 is a protection transistor for M0.

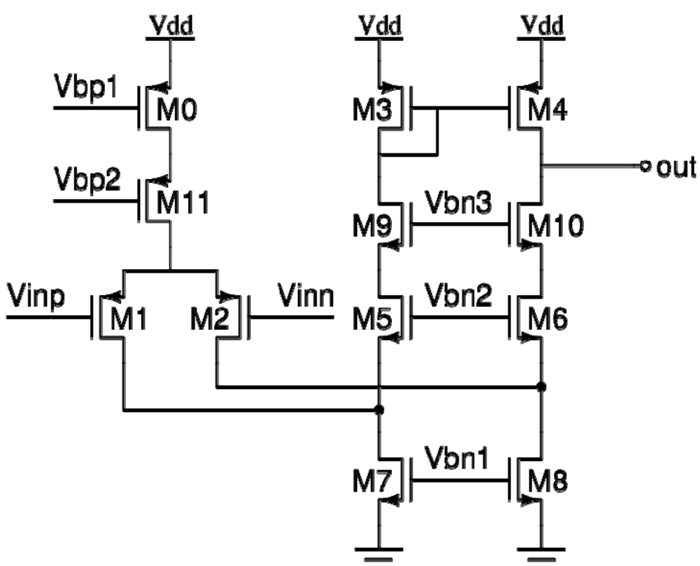

Figure 2: Folded Cascode OTA Design to Shift Output Voltage Range to Higher Voltages

The general folded cascode OTA design has a full swing output voltage (0 to VDD, reduced by transistor imperfection). In contrast, the folded cascode OTA design presented herein has a reduced/limited and shifted output swing (e.g., VDD/2 to VDD) in order to limit voltage stress at the subsequent stage.

By employing cascodes at different places and at different control voltages, the output span can be shifted to middle or lower output voltage operation, while limiting the output range, as illustrated in Figures 3 and 4, below. For the design illustrated in Figure 3, Vbp3 sets the upper limit for the output signal and for the design in Figure 4, Vbp3 and Vbn3 are used to set upper and lower limits.

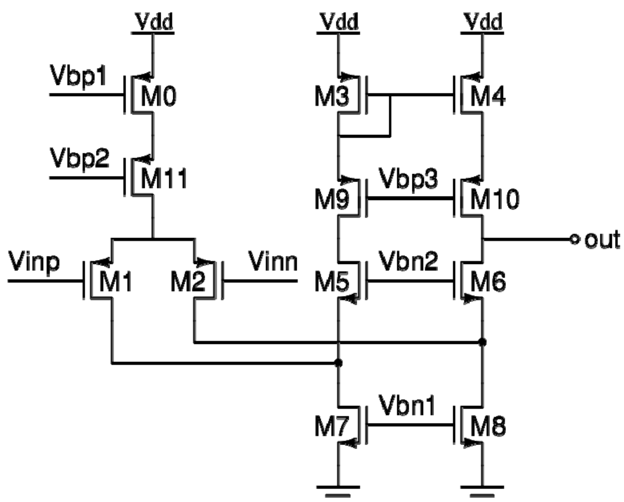

Figure 3: Folded Cascode OTA Design with Low Output Range

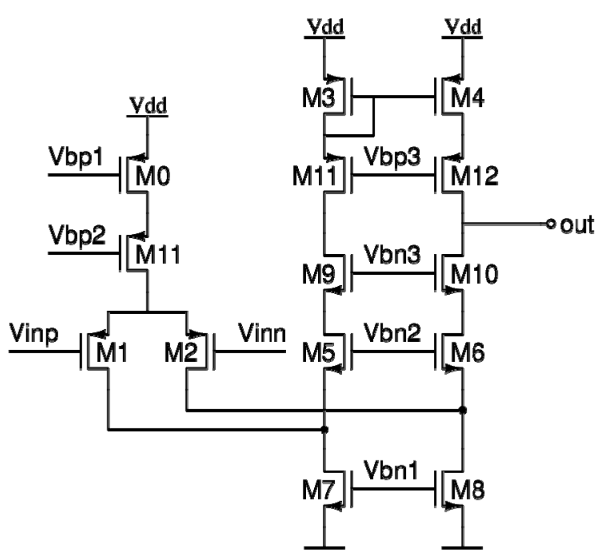

Figure 4: Folded Cascode OTA Design with Middle Output Range

Figure 5, below, illustrates a typical application involving a classical low-dropout (LDO) circuit that may utilize the folded cascode OTA design described herein. In particular, the low-in/high-out variant may be utilized for the application illustrated in Figure 5 in which the low voltage area is marked in green and the high voltage area is marked in orange.

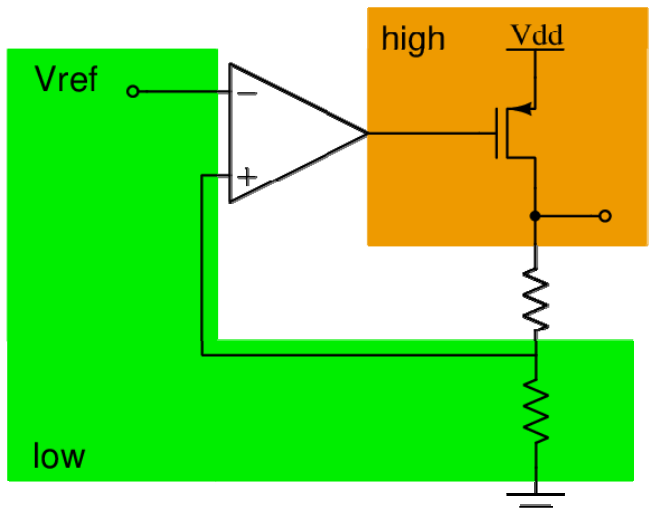

Figure 5: Example LDO Application

In summary, this proposal provides a folded cascode OTA design that can operate with a power supply voltage greater than the VDS breakdown voltage in which the output range can be limited to the VGS breakdown range and can be adapted to a desired range using a cascode transistor. By employing cascodes at different places and at different control voltages, the output span can also be shifted to middle or lower output voltage operation, while limiting the output range. Additionally, the folded cascode OTA design presented herein can operate safely in non-switched applications.