# Current Sources (and sinks)—understanding compliance range



We get many questions on our forums about designing current sources of all types—constant currents, voltage-controlled currents, AC currents, high currents, low currents, active current sources and passive current sinks. All different kinds. A single blog can't begin to cover all this ground. I can, however, provide some basic background and links for more information.

A key point: A current source cannot force a current to flow into a load without applying the necessary voltage. Think of a current source as a circuit that adjusts its output voltage to cause the desired current to flow in the load. You can't make a 10mA current flow into a 1k-ohm load without applying 10V. Or perhaps, more to the point, you can't make 10mA flow into a into a 100kΩ load without somehow creating a 1000V output. We get periodic requests for simple op amp circuits that will perform this magic without a 1000V op amp, or even a 1000V power supply.

As one of my colleagues says, "***It's Ohm's Law, not Ohm's inconvenient suggestion***." (Thanks for that one, John!)

The point here is to understand the *compliance voltage range* of a current source. This is the voltage range over which the circuit can maintain a constant current. I'll use the circuit in figure 1 (actually a current sink) as an example, a circuit designed and modified by countless engineers.

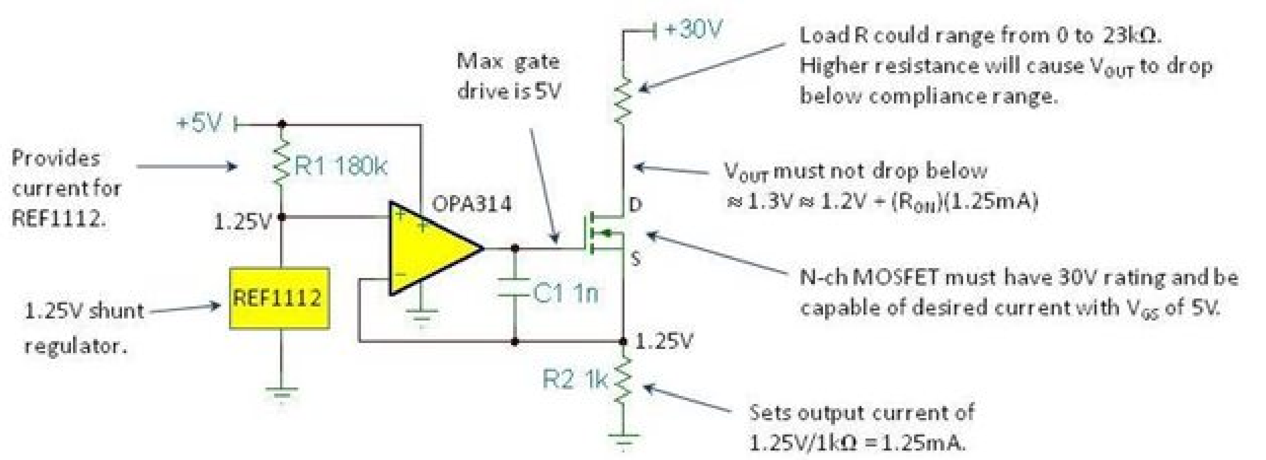


Figure 1.

A reference voltage is created at the input of the op amp using the REF1112 shunt regulator (like a zener diode but low voltage). This same voltage is replicated through feedback on R2. This sets the output current because the drain current is virtually identical to the source current. Engineers like to "read pictures" so I encourage to digest the notes in this diagram.

The simulation in figure 2 graphically shows the compliance voltage range of this circuit. The voltage source Vs is swept from 0V to 30V. In this case, the load voltage, VOUT is the same as Vs, the voltage on the drain of the MOSFET. Notice that as Vs increases 0V to 1.2V the output current, Iout, climbs steadily. Through this range, there is not yet enough voltage for proper operation. Once Vs reaches just over 1.2V the current regulates at the expected value of 1.25mA, remaining constant up to 30V. 1.3V to 30V is the compliance range of this current sink. The simulation is stopped at 30V, the voltage rating of the selected MOSFET. A higher voltage MOSFET, and higher supply voltage could greatly increase the compliance range of this current sink.

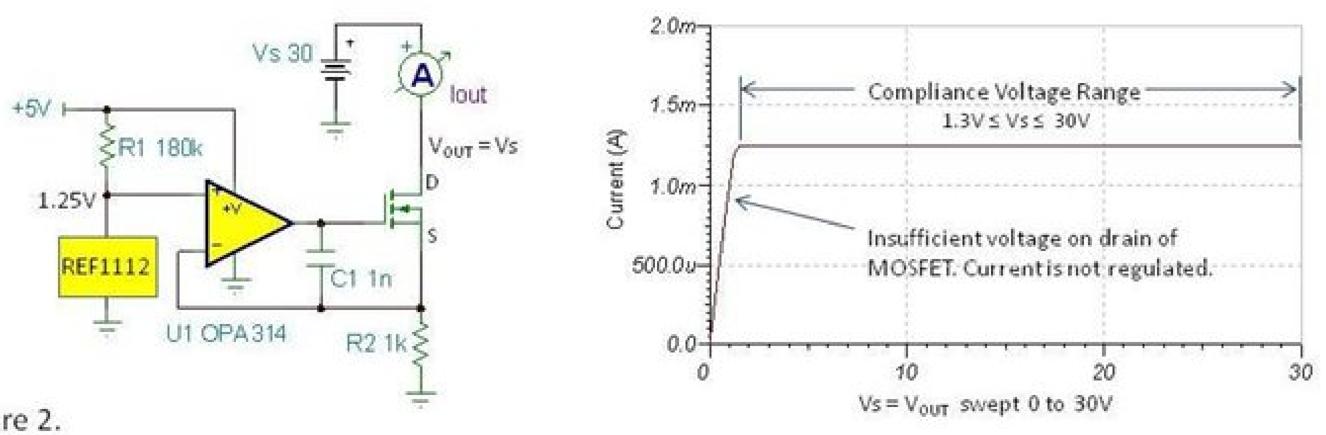

Figure 2.

There are countless current sources circuits of all types. All have limits to their compliance voltage range. With some thought and care you can select a current source type and optimize it for your needed compliance range.

Here are two excellent references documents. Both are from late analog experts whose legacy lives on:

Mark Stitt, my friend and colleague wrote this comprehensive application bulletin.

Implementation and Applications of Current Sources and Current Receivers

It prominently features the REF200, a versatile, integrated 2x 100uA current source, a skunk-works project on which we jointly conspired. It covers far more than that, a great general reference document. RIP RMS.

Analog giant, Bob Pease, wrote this article on the Howland current pump (current source/sink). It's an excellent reference, complete with Bob's beautifully intuitive explanations of the Howland. RIP RAP.

A Comprehensive Study of the Howland Current Pump

If you have a favorite reference article on current sources, please share it with all of us.

Thanks for reading,

Bruce

R_Sam Hi Bruce,

The above information provided by you is very helpful. I would like to ask that using above circuit is it possible to achive the current output in the picoampere range. And also how the load R value is calculated.

Bruce Trump R_Sam-- Scaling this type of circuit to very low current would be difficult. The challenge would be finding a transistor that is specified for extremely low leakage current as this would be the primary source of error. Of course, the op amp used would also require extremely low input bias current. The inverting input bias current would create an error. at very low current, load resistance could vary over an extremely wide range--from zero to approximately 29V/Iout in this example. --Bruce.

Tao Wang1 Hi Bruce,

I am goona ask you a question since I am now investigating the issue of the compliance voltage. First, a simulation is made to generate biphasic current source. At the output end, a resistor is in series with a capacitor which allows biphasic current source to flow through. The stimulator power is 12V. In order to hit the compliance, external power supply is added to control the stimulator and adjustable. When the power supply is adjusted to 7V( go into the compliance) for exmaple, the voltage across the resistor and capacitor happens to be flat (RC circuit is charging). Then the cuurent through the resistor will change (not a constant current any more but seems like a linear current decreasing which is observed from oscilloscope).

Why would this happen? Thanks.

Bruce Trump Tao-- Sorry, but I am not sure that I understand your question. Comments posted to blogs do not allow you to include schematics. If you would post your question to the Precision Amplifiers forum (link below) I would be pleased to attempt an answer. Please include a complete schematic so that I can better understand you question. Regards, Bruce.

e2e.ti.com/.../default.aspx