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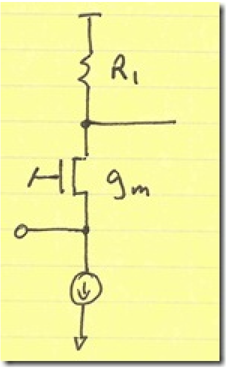
The case for the trans-conducting LNA

By POOJAN WAGH | *Published:* NOVEMBER 1, 2008

In this post, I will show an evolution of a trans-conducting LNA (rather than a voltage-gain LNA). This is a prime example of current-mode circuit design, which has benefits in terms of linearity—especially for low-voltage scaling in RFCMOS design.

Conventional common-gate LNA

Consider the conventional common-gate LNA on its own:



This LNA consists of an input at the source of the MOS transistor (or emitter of a BJT) , a current-source to bias the transistor, and a resistor load. This configuration is typically used in broadband receivers (cable tuners, TV tuners, software-defined radio).

The gain of this stage is $A_V = g_m \times R_1$. This seems like a reasonable stage to produce a gain and therefore overcome noise.

Each of these circuits is presented as a single-ended version. However, there is absolutely no reason not to implement them as differential circuits. I merely draw them single-ended here to get the point across without obfuscating the primary ideas. If there is interest in seeing what the differential versions look like, please post a request in the comments section.

CMOS LNM employing voltage-mode LNA

However, consider what happens when we couple this LNA into a CMOS switch-mode mixer:

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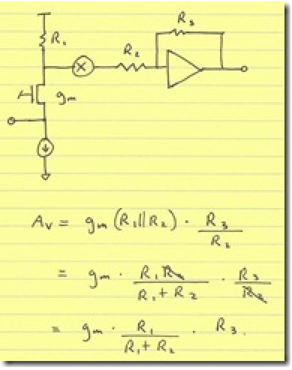
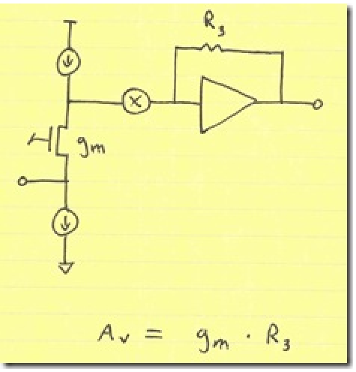


The ⊗ symbol represents a set of commutating MOS mixers, typically capacitively coupled, to separate the dc bias voltages at the output of the LNA and the input of the post-mixer amplifier (PMA). You can essentially ignore then in this analysis, and just assume that they ideally convert from RF to baseband (direct conversion).

Consider the loss term $R1/(R_1 + R_2)$. It doesn't have to be there.

Trans-conducting LNA

If we replace R1 with a current-source load and merely omit R2, we'd have something like this:



You'll note that the previous loss term is now gone. We have greatly enhanced the gain at essentially no cost. Furthermore, the resulting architecture is even more linear: there is little swing at the output of the LNA; the summing junction of the PMA linearizes the LNA by presenting a low impedance to the LNA.

Due to the high output impedance of the LNA, a common-mode feedback circuit is necessary. I have detailed two ways of doing that.

References

Matt Miller and I came up with these ideas at Motorola in 2004. We were not the only ones. Other people within Motorola came up with the same idea. In addition, I had seen it published somewhere around 2004—I thought by Michiel Steyaert or Thomas Lee. Despite my recollection, the closest references I have seen available are: "A 72mW CMOS 802.11a direct conversion receiver with 3.5dB NF and 200kHz 1/f noise corner" (albeit using an inductor load instead of PMOS loads) and "A 1 V 1.1 GHz CMOS integrated receiver front-end" (with a folded Gilbert cell mixer).

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3 Comments

ashvini vishvakarma
Posted June 14, 2009 at 11:55 pm | *Permalink*

hi poojan,
i love your analog desgn insight posts.

'current mode design' is a bit of a black art for me. and there is only ONE book in entire Amazon on it !

Can you pl write an article on rough rules of thumb to use for (1) when to use current mode and (2) how 2 go about designing in current mode.

can you pl also write a post on why the OTA [operational trans-conductance amplifier] failed to 'take over the world' ? what caused its demise ? and is it still used in some neiche ? what is that neiche ?

I know about the 4-20 ma current loop of Induatrial, and the teleco current loop for POTS onhook-offhook detection.

ashvini, new delhi , india.

Log in to reply.

Poojan Wagh
Posted December 28, 2008 at 10:22 pm | *Permalink*

@Robert Tso:

You're right about the impedance going high outside of the gain-bandwidth of the op-amp. Typically, you'll want to put a capacitor on the inputs of the PMA to maintain a low impedance when the PMA's op-amp (OTA) runs out of steam (and to suck out any LO injection). The addition of such a capacitor is not trivial as it can really screw up stability.

I also recall that there's a filter configuration (was it Tow-Thomas?) that includes such a capacitor.

I will admit ignorance on many of the details of the BBF, because there was either someone else to do that job (which, I will admit, is the crux of this configuration), or I was always pulled off to other tasks.

Log in to reply.

Robert Tso
Posted December 24, 2008 at 3:06 pm | *Permalink*

If the post mixer amplifier is a low bandwidth amplifier, then it will not do a very good job in presenting a low impedance at the mixer output or at the gm stage output, – so the benefits of improving gm stage linearity would not be realized
The likely advantage of the 2nd schematic configuration is that it allows a filter to be placed between the mixer and baseband amp.

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- By The benefits of differential circuits on May 17, 2012 at 10:52 pm

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