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Integrated Low Noise Multi-Chip Amplifier Modules
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To amplify weak signals received by the antenna in communication systems, low noise amplifiers (LNAs) are deployed. LNAs are used in various applications, for example in, GPS receivers, wireless data systems, satellite communication, cellular handsets, radio systems, etc. The low noise in the receive chain is reduced by the gain of the LNA and therefore the function is primarily to boost the signal power while adding minimum noise and distortion to the signal. Low noise figure (NF) therefore results in improved reception of the received signal.

The demand for integrated solutions with minimum external components is increasing due to its easy deployment in wireless infrastructure systems. Apart from the LNA, the module palette has contribution towards the device’s performance and hence the usual bill of materials (BOM) or passive matching network used with, for example, Skyworks’ independent packaged LNA in DFN (8-pin, 2x2 mm2 package) may not be the same as in an integrated LNA. The module has its noise and distortion contribution and therefore has to be carefully designed keeping the best performance from the LNA used for a respective frequency band. The most critical parameters required from LNAs are noise figure, gain, impedance matching, and non-linearity. After printed circuit board (PCB) placement and routing for the MCM, the stand alone LNA package is tuned with new matching components to achieve best performance from these mentioned parameters.
The family of products presented here are high performance, low noise single stage amplifier modules designed for use at 0.4 to 3.0 GHz wireless applications. Targeted applications are mainly GSM, CDMA, WCDMA, TD-SCDMA, WiMAX, ISM, LTW cellular infrastructure, and ultra low noise systems.

Figure 2: Bias Currents vs. External Resistance
The modules comprise of a single stage high linearity, high gain low noise GaAs pHEMT amplifier along with the matching components, greatly reducing PCB area and offering low thermal resistance for enhanced mean time between failure (MTBF). The module is also completely DC bypassed and is realized in a 4 x 4 mm² 16-pin package. LNAs active bias circuitry internally provides stable performance over temperature and process variations. The module also offers the ability to use its only external component to adjust the supply current and has been tested to operate over the temperature range of 40 to +85 °C.
Any additional information required can be made available by the marketing and designing team of Skyworks Solutions, Inc. If a new application from a customer requires a specialized integrated module, requests may be forwarded to the marketing team as well. This brief will highlight the following:

1. Description of the integrated module and type of LNA deployed in the multi-chip-module (MCM).

2. Performance at respective frequency bands along with their operational temperature measurements.

**Design and Configuration**

*Figure 1* shows the block diagram of the module proposed which encloses the complete input and output matching components including DC bypassing components. The operating current will be set through the external resistor component, R1.
A typical set of bias current vs. resistor values is shown in Figure 2. The recommended range of bias current for operating the modules is from 25 – 110 mA, with operating voltages that can range from 3.3 – 5.0 V. Operating the devices anywhere within these ranges of bias conditions is acceptable. Some performance changes will be noted as these bias conditions are varied, but stability will be maintained vs. operating and temperature conditions. An important note on the thermal property of the LNA package used in the module -- the LNA together with the thermal conductivity of die-attach, over-mold and MCM package, can withstand an operating current of 110 mA at 100 °C.
As mentioned earlier, performance changes may occur and extending the external limits on the modules may reduce device reliability. However the matching in the module has been designed to compensate for changing operating conditions.

*Figure 6: Input Return loss (S11)*
Although the LNA module’s stability at all frequencies is obtained from included internal bypass capacitors, additional external bypassing to both the VDD and VBIAS bias lines could be added in the form of a 10,000 – 100,000 pF capacitors, (C1, C2) if required as shown in Figure 3. These bypass capacitors are not necessary for the device’s operation but may, however, improve the stability of the amplifier especially at lower frequencies.
The diagram of the applications circuit deploying the integrated LNA module on the evaluation board (EVB) is shown in Figure 4. Note the simplicity of the final design circuit where all the matching components are internal to the device. Therefore, procurement of critical components as well as their stocking fee for a large variety of components is now eliminated. Each component is also 100 percent tested before shipment, so failure rates from final tests at the customer’s end is greatly reduced.
Typical Performance Data
We have designed four integrated LNA modules to cover critical RF bands from 0.4 to 3.0 GHz. For example let’s consider the SKY67221 targeting 1.6 -2.1 GHz. Figure 5 to 8 highlights its typical small signal performance at 5V, 85mA. Clearly in the 1.95 GHz band of interest, return loss/S11 is tuned for < -25 dB which can make this device very simple to match to other 50 Ohm devices. Similarly keeping an acceptable output return loss, the S22 has been tuned mostly to enhance the input third-order intercept point (IIP3) performance. Typical IIP3 at 1.95 GHz is +18 dBm and corresponding output third-order intercept point (OIP3) of +37 dBm, Figure 10, when biased at 5.0 V, 85 mA.
The SKY67221’s typical NF vs. temperature is shown in Figure 9. NF performance includes a correction factor (0.03 from EVB) that has been added to the NF plot. This correction factor has been kept very conservative for the loss of the PC Board input trace and SMA connector up to the module’s pin. Overall the excellent low noise performance and high intercept point performance makes this module a competitive fit both as a first stage LNA and as a good second stage driver amplifier.
Broadband stability vs. frequency and temperature is shown in Figures 11 and 12. Stability factors vs. bias voltage and currents stays quite uniform and controlled. It is however very important that the applications circuit grounding of the device paddle be adhered to (Figure 4). This will ensure a good thermal contact as well as provide a low inductance path to ground for terminating RF currents (Paddle Pin 17, Figure 3).
The modules have been tested for electro-static discharge (ESD) as well. These four integrated LNA modules’ ESD threshold has been verified to be 500 V (Class 1B) using human body model (HBM) testing. Also the device passed 50 V (Class A) with machine model (MM) testing and 1000 V (Class IV) with charged device model (CDM) testing.

Low Noise Module Product Family Specifications

Including the SKY67221 from the example in the last section, we have three other integrated LNA modules, the SKY67215, SKY67216 and SKY67226, with central frequencies at 450 MHz, 850 MHz and 2.5 GHz respectively. The performance of each integrated LNA module is highlighted in Table 1. The modules cover the 400 MHz – 3 GHz frequency bands of interest. Each device is pin compatible with the other and offer outstanding performance at their respective frequency band. The performance specifications are similar to the SKY67221 discussed earlier with similar return loss, stability, and ESD protection.
Conclusion
We have presented here four integrated LNA modules in 4 x 4 mm2 16-pin package. Good NF with unconditional stability, high linearity, good gain, all in a reasonably broad bandwidth makes them essential building blocks ready to be deployed in today’s wireless infrastructure systems. These modules can also be cascaded, if desired, with no need for inter-stage blocking or matching. Also due to excellent return loss characteristic, filtering in front, in-between or at the output of each module can be easily implemented.

Further we have shown that these modules can also be operated over a wide range of current and voltages, making them suitable for lower power applications as well, while maintaining good performance. They are robust with better ESD protection compared to other LNAs in the industry.

These LNA modules expand Skyworks’ MMIC product portfolio in enhancement mode (E-mode) pHEMT amplifiers with below 1 dB NF and high linearity performance. Their fully integrated specifications with very compact space saving design meets the increasing demand of integrated LNA solutions.

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