This application note describes the schematic and layout requirements for using the BGA3015 and BGA3018 drop amplifiers together with the BAP70Q quad pin diode in a CATV VGA application.
Hisection.

Contact information

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For sales office addresses, please send an email to: salesaddresses@nxp.com
1. Introduction

With the use of NXP’s BGA301x drop amplifiers and the BAP70Q quad pin diode attenuator a wideband Variable Gain Amplifier (VGA) has been made which can be used as line-up amplifier in CATV networks.

The combination of NXP’s BGA301x amplifiers and BAP70Q pin diode parts a high gain amplifier with low noise figure and wide dynamic range can be made.

This application note describes the evaluation board schematic and layout requirements, and shows the test results.

2. System features

- 75 Ω input and output impedance
- Gain control dynamic range of 20 dB
- Flat gain between 40 MHz and 1003 MHz
- Unconditionally stable
- Excellent input and output return loss

3. Customer evaluation kit contents

The evaluation kit contains the following items:

- ESD safe casing
- BGA301x VGA evaluation board
4. Application information

The evaluation circuit can be seen in figure 1 and the corresponding PCB is shown in figure 2. Table 1 shows the bill of materials.

4.1 Evaluation board circuit

The connector pinning is as followed:

- “GND”: Ground pins
- “Vamp1”: +8 V power supply for amplifier U1
- “Vamp2”: +8 V power supply for amplifier U3
- “Vcc”: +8 V power supply for pin diode attenuator U2
- “Vctr”: Pin diode attenuator control voltage (1 … 3 V)

At connector J1 the RF signal from an external optical receiver is applied, where C1 provides DC-blocking, followed by L1 for S11 matching of the BGA3018 amplifier (U1).

The feedback of amplifier U1 is provided via R1 & R2 with C2 for DC-blocking between the input and output pins of the amplifier. Two resistors are used to lower the influence of the parasitic capacitance from the circuit board. The output of amplifier U1 is matched with L4 and C6 provides the DC-blocking towards pin-diode attenuator U2.

The signal out of the first amplifier has a large dynamic range and with use of the BAP70Q pin diode attenuator (U2) the RF signals can be attenuated in such a way that a stable RF signal will be available at the output of the pin-diode attenuator. The stable output signal is amplified again by the BGA3015 amplifier (U3).

C10 provides DC-blocking, followed by L7 for S11 matching of the BGA3015 amplifier (U3). The feedback of amplifier U2 is provided via R10 & R11 with C11 for DC-blocking between the input and the output pins of the amplifier. Two resistors are used to lower the influence of the parasitic capacitance from the circuit board. The output of amplifier U3 is matched with L10 and C15 provides the DC-blocking towards the output connector J2.
4.2 Evaluation board layout

For optimum distortion performance it is important to have enough ground vias underneath and around the MMICs ground pins. This lowers the inductance to the ground plane. The evaluation board is made with two layer FR4 material.
## 4.3 Bill of materials

Table 1. Evaluation board BoM

<table>
<thead>
<tr>
<th>Circuit reference</th>
<th>Description</th>
<th>Qty</th>
<th>Mfr</th>
<th>Manufacturer number</th>
<th>Supplier</th>
<th>Supplier part number</th>
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<td>BGA3018</td>
<td>1</td>
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<td>NXP</td>
<td>BGA3018</td>
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<td>U2</td>
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<td>BAP70Q</td>
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<tr>
<td>U3</td>
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<td>BGA3015</td>
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<td>C1, C2, C3</td>
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<td>GRM155R71E103KA01D</td>
<td>Digikey</td>
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<td>C6, C7, C8</td>
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<td>C4, C13</td>
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<td>C5</td>
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<td>L1, L10</td>
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<td>L2, L6, L9</td>
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<td>L7</td>
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<td>311-0.0LRCT-ND</td>
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<td>J1, J2</td>
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<td>WM8112-ND</td>
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5. Measurement results at Vcc = 8 V

5.1 S-Parameters

a. S11: 40 MHz – 1140 MHz
   (1): Vctr = 2.13 V
   (2): Vctr = 1.80 V
   (3): Vctr = 1.64 V
   (4): Vctr = 1.50 V
   (5): Vctr = 1.39 V
   (6): Vctr = 1.29 V
   (7): Vctr = 1.12 V

b. S11: 300 kHz – 200 MHz
   (1): Vctr = 2.13 V
   (2): Vctr = 1.80 V
   (3): Vctr = 1.64 V
   (4): Vctr = 1.50 V
   (5): Vctr = 1.39 V
   (6): Vctr = 1.29 V
   (7): Vctr = 1.12 V

Fig 3. Input matching (S11); Vcc = 8 V

a. S22: 40 MHz – 1140 MHz
   (1): Vctr = 2.13 V
   (2): Vctr = 1.80 V
   (3): Vctr = 1.64 V
   (4): Vctr = 1.50 V
   (5): Vctr = 1.39 V
   (6): Vctr = 1.29 V
   (7): Vctr = 1.12 V

b. S22: 300 kHz – 200 MHz
   (1): Vctr = 2.13 V
   (2): Vctr = 1.80 V
   (3): Vctr = 1.64 V
   (4): Vctr = 1.50 V
   (5): Vctr = 1.39 V
   (6): Vctr = 1.29 V
   (7): Vctr = 1.12 V

Fig 4. Output matching (S22); Vcc = 8 V
Fig 5. Gain (S21); Vcc = 8 V

a. S21: 40 MHz – 1140 MHz
   (1): Vctr = 2.13 V  
   (2): Vctr = 1.80 V  
   (3): Vctr = 1.64 V  
   (4): Vctr = 1.50 V  
   (5): Vctr = 1.39 V  
   (6): Vctr = 1.29 V  
   (7): Vctr = 1.12 V  

b. S21: 300 kHz – 200 MHz
   (1): Vctr = 2.13 V  
   (2): Vctr = 1.80 V  
   (3): Vctr = 1.64 V  
   (4): Vctr = 1.50 V  
   (5): Vctr = 1.39 V  
   (6): Vctr = 1.29 V  
   (7): Vctr = 1.12 V  

Fig 6. K-factor; typical; Vcc = 8 V

a. K-factor: 40 MHz – 1140 MHz
   (1): Vctr = 2.13 V  
   (2): Vctr = 1.80 V  
   (3): Vctr = 1.64 V  
   (4): Vctr = 1.50 V  
   (5): Vctr = 1.39 V  
   (6): Vctr = 1.29 V  
   (7): Vctr = 1.12 V  

b. K-factor: 300 kHz – 200 MHz
   (1): Vctr = 2.13 V  
   (2): Vctr = 1.80 V  
   (3): Vctr = 1.64 V  
   (4): Vctr = 1.50 V  
   (5): Vctr = 1.39 V  
   (6): Vctr = 1.29 V  
   (7): Vctr = 1.12 V  
5.2 Distortion

Fig 7. Composite triple beat (CTB); Vcc = 8 V

Fig 8. Composite second order (CSO); Vcc = 8 V
(1): $V_{ctr} = 2.13 \, V$
(2): $V_{ctr} = 1.64 \, V$
(3): $V_{ctr} = 1.39 \, V$
(4): $V_{ctr} = 1.12 \, V$

132 channels NTSC, $V_o = 30 \, $dBmV

**Fig 9.** Cross modulation (XMOD); $V_{cc} = 8 \, V$
5.3 Noise figure

Fig 10. Noise figure; Vcc = 8 V

(2): Vctr = 1.80 V  (6): Vctr = 1.29 V
(3): Vctr = 1.64 V  (7): Vctr = 1.12 V
(4): Vctr = 1.50 V
6. Measurement results at Vcc = 5 V

6.1 S-Parameters

a. S11: 40 MHz – 1140 MHz
   - (1): Vctr = 2.13 V
   - (2): Vctr = 1.80 V
   - (3): Vctr = 1.64 V
   - (4): Vctr = 1.50 V
   - (5): Vctr = 1.39 V
   - (6): Vctr = 1.29 V
   - (7): Vctr = 1.12 V

b. S11: 300 kHz – 200 MHz
   - (1): Vctr = 2.13 V
   - (2): Vctr = 1.80 V
   - (3): Vctr = 1.64 V
   - (4): Vctr = 1.50 V
   - (5): Vctr = 1.39 V
   - (6): Vctr = 1.29 V
   - (7): Vctr = 1.12 V

Fig 11. Input matching (S11); Vcc = 5 V

a. S22: 40 MHz – 1140 MHz
   - (1): Vctr = 2.13 V
   - (2): Vctr = 1.80 V
   - (3): Vctr = 1.64 V
   - (4): Vctr = 1.50 V
   - (5): Vctr = 1.39 V
   - (6): Vctr = 1.29 V
   - (7): Vctr = 1.12 V

b. S22: 300 kHz – 200 MHz
   - (1): Vctr = 2.13 V
   - (2): Vctr = 1.80 V
   - (3): Vctr = 1.64 V
   - (4): Vctr = 1.50 V
   - (5): Vctr = 1.39 V
   - (6): Vctr = 1.29 V
   - (7): Vctr = 1.12 V

Fig 12. Output matching (S22); Vcc = 5 V
a. $S_21$: 40 MHz – 1140 MHz

(1): $V_{ctr} = 2.13\ V$
(2): $V_{ctr} = 1.80\ V$
(3): $V_{ctr} = 1.64\ V$
(4): $V_{ctr} = 1.50\ V$
(5): $V_{ctr} = 1.39\ V$
(6): $V_{ctr} = 1.29\ V$
(7): $V_{ctr} = 1.12\ V$

b. $S_21$: 300 kHz – 200 MHz

(1): $V_{ctr} = 2.13\ V$
(2): $V_{ctr} = 1.80\ V$
(3): $V_{ctr} = 1.64\ V$
(4): $V_{ctr} = 1.50\ V$
(5): $V_{ctr} = 1.39\ V$
(6): $V_{ctr} = 1.29\ V$
(7): $V_{ctr} = 1.12\ V$

Fig 13. Gain ($S_21$); $V_{cc} = 5\ V$

a. $S_21$: 40 MHz – 1140 MHz

(1): $V_{ctr} = 2.13\ V$
(2): $V_{ctr} = 1.80\ V$
(3): $V_{ctr} = 1.64\ V$
(4): $V_{ctr} = 1.50\ V$
(5): $V_{ctr} = 1.39\ V$
(6): $V_{ctr} = 1.29\ V$
(7): $V_{ctr} = 1.12\ V$

b. $S_21$: 300 kHz – 200 MHz

(1): $V_{ctr} = 2.13\ V$
(2): $V_{ctr} = 1.80\ V$
(3): $V_{ctr} = 1.64\ V$
(4): $V_{ctr} = 1.50\ V$
(5): $V_{ctr} = 1.39\ V$
(6): $V_{ctr} = 1.29\ V$
(7): $V_{ctr} = 1.12\ V$

Fig 14. $K$-factor; typical; $V_{cc} = 5\ V$
6.2 Distortion

![Graph showing CTB and CSO with frequency in MHz and dBc]

- (1): $V_{ctr} = 2.13\, V$
- (2): $V_{ctr} = 1.15\, V$
- (3): $V_{ctr} = 1.00\, V$
- (4): $V_{ctr} = 0.84\, V$

132 channels NTSC, $V_o = 30\, \text{dBmV}$

**Fig 15.** Composite triple beat (CTB); $V_{cc} = 5\, V$

![Graph showing CSO with frequency in MHz and dBc]

- (1): $V_{ctr} = 2.13\, V$
- (2): $V_{ctr} = 1.15\, V$
- (3): $V_{ctr} = 1.00\, V$
- (4): $V_{ctr} = 0.84\, V$

132 channels NTSC, $V_o = 30\, \text{dBmV}$

**Fig 16.** Composite second order (CSO); $V_{cc} = 5\, V$
Fig 17. Cross modulation (XMOD); Vcc = 5V

(1): Vctr = 2.13 V  (3): Vctr = 1.00 V
(2): Vctr = 1.15 V  (4): Vctr = 0.84 V

132 channels NTSC, Vo = 30 dBMV
6.3 Noise figure

![Graph showing noise figure for different Vctr values. The graph plots noise figure in dB against frequency in MHz.](image)

(1): Vctr = 2.13 V  
(2): Vctr = 1.27 V  
(3): Vctr = 1.15 V  
(4): Vctr = 1.07 V  
(5): Vctr = 1.00 V  

**Fig 18. Noise figure; Vcc = 5 V**
7. Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>CATV</td>
<td>Community Antenna Television</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>ESD</td>
<td>Electro Static Discharge</td>
</tr>
<tr>
<td>MMIC</td>
<td>Monolithic Microwave Integrated Circuit</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>SMD</td>
<td>Surface Mounted Device</td>
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8. Legal information

8.1 Definitions

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