

Application Note 4112

The Selection Guide for Appropriate Motor Drive ICs In Optical Media Applications

1. The need for gain adjustment and the various input stage schemes

Optical media systems have many motors (including actuators) and most of them are DC motors. A Balance Transformer-less (BTL) driver is commonly used to operate these motors. Figure 1 shows a typical block diagram.

The total gain can be described as shown in equation 1

$$\text{Gain}_{\text{total}} = \frac{V_{\text{out}}}{V_{\text{in}}} = A_{\text{in}} \times A_{\text{p}} \quad (1)$$

Where, A_{in} is the gain of the input stage and A_{p} is the gain of the power amplifier. Generally A_{p} is a fixed value within the IC, so A_{in} is used to change the overall total gain. Because of various DSP operating voltages, power amplifier supply voltages and the actuator's physical dynamic ranges, the total gain should be adjusted to fit the specific application.

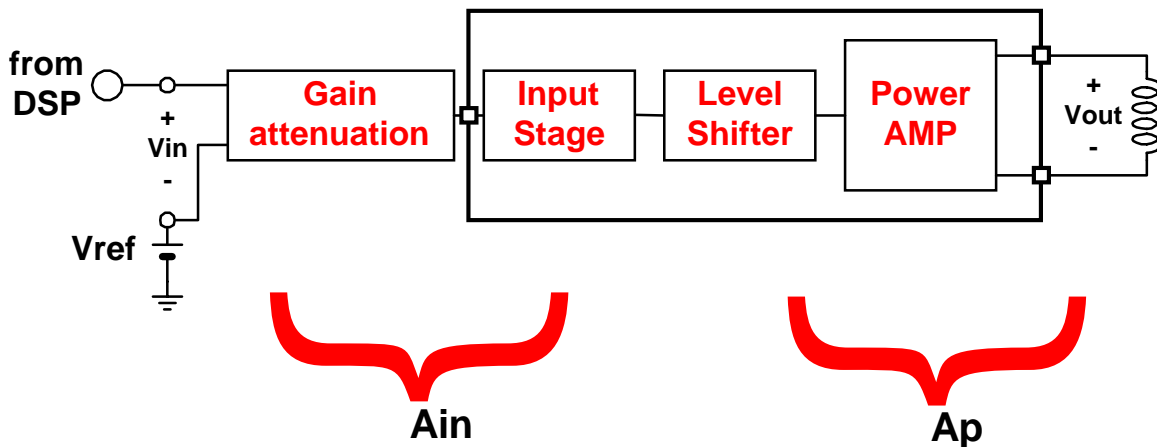
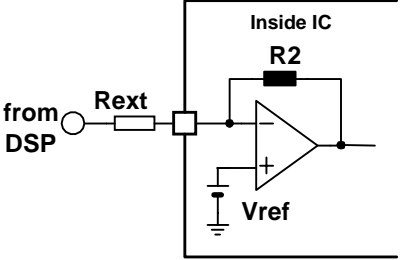
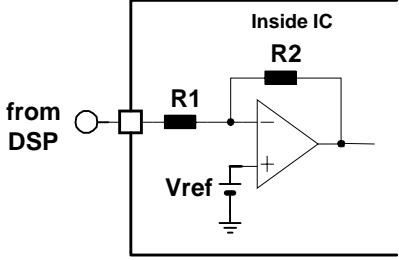
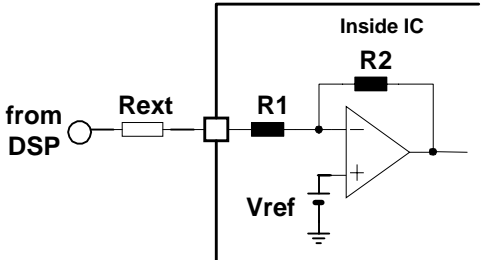
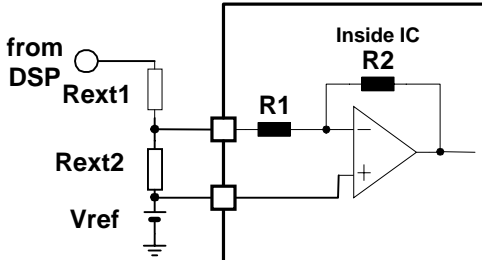
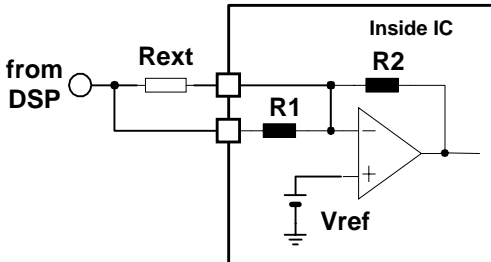
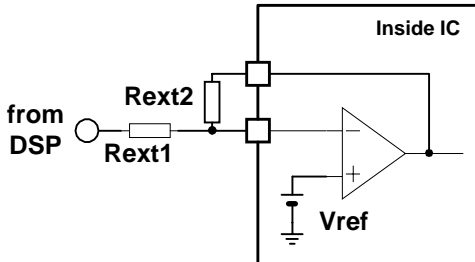
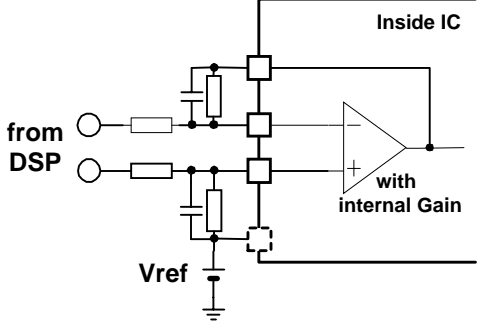
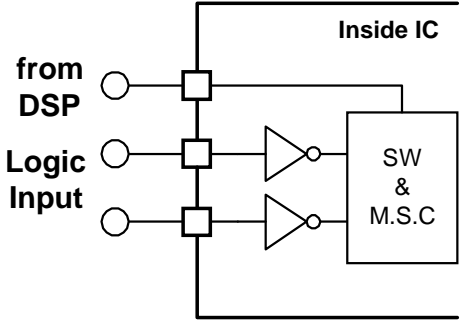


Figure 1. Overall block diagram

Table 1. Classification of input stage schemes

| | |
|---|--|
|  |  |
| <p>Type A</p> | <p>Type B.1</p> |
|  |  |
| <p>Type B.2</p> | <p>Type B.3</p> |
|  |  |
| <p>Type C</p> | <p>Type D</p> |
|  |  |
| <p>Type E</p> | <p>Type L</p> |

Without gain adjustment, the available resources can't be used properly. For example V_{in} is 1.5V in a 3.3V DSP application, the motor supply power V_M is 12V, A_p is 4 and A_{in} is 2. In this condition the output voltage is $1.5 \times A_p \times A_{in} = 12V$. But when V_M is changed to 5V, the maximum output voltage is only 5V. This means that the input range is limited to 0.8V. If A_{in} is adjusted to a lower value, this situation can be avoided. Fig. 2 describes this example. Another example shows power loss in the output stage due to a change in the DSP operating voltage. When V_{in} is 2.5V in a 5V DSP application, V_M is 5V, A_p is 2 and A_{in} is 1, then the output voltage is $2.5 \times A_p \times A_{in} = 5V$. If V_{in} is decreased to 1.5V because of a 3.3V DSP application, the output voltage

is only 3V. In this case the surplus power that is $(V_M - 3V) \times I$ [current] means that there is a power loss. This is described in fig. 3.

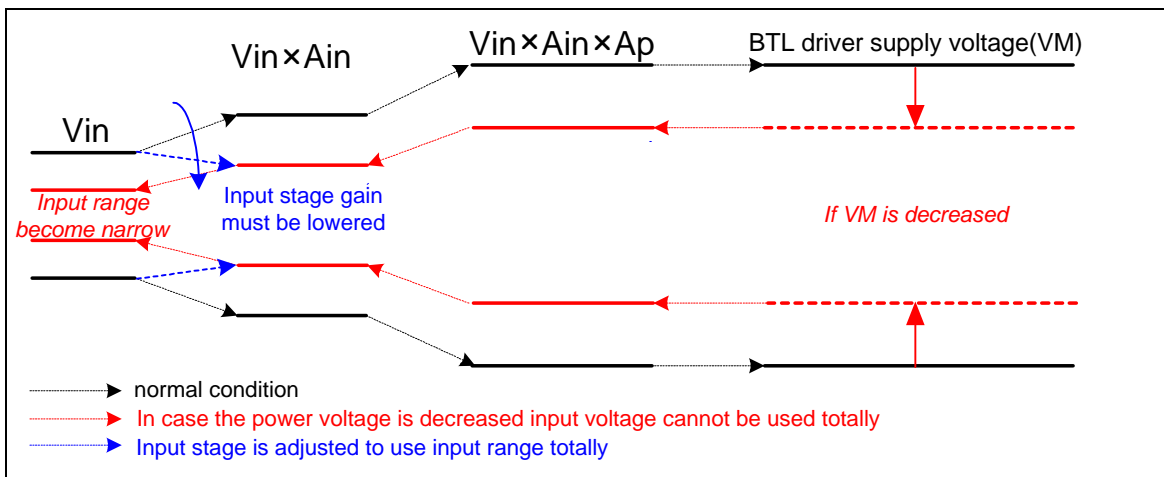


Figure 2. Gain adjustment process when motor supply voltage is changed

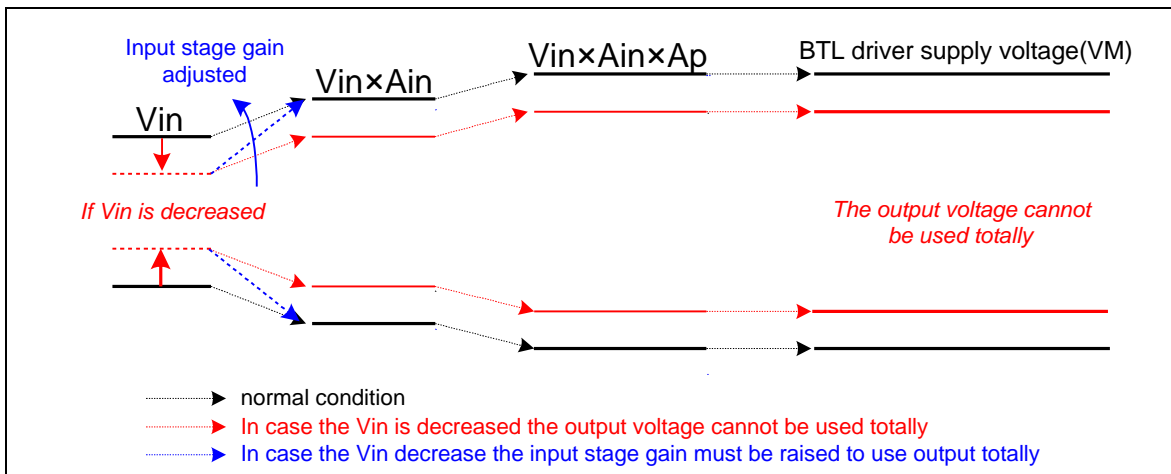


Figure 3. Gain adjustment process when DSP chipset voltage is changed

The user can select any type of motor drive IC and change total gain to any value according to the system configuration. Hence, the input stages of the motor drive ICs have various schemes to serve flexible total gain adjustment methods as shown in table.1 The schemes are classified into 8 possible methods in Fairchild's linear BTL drivers.

The total gain adjustment means to not only change A_{in} but also the ICs. The input stage gain A_{in} is made up of input OP-amp gain and the ratio of the resistors. Some other criterion is required in selecting the device, because the difference in the temperature coefficient between internal and external resistor results in total gain variation. The influence of temperature variation and a possible solution is explained in the following paragraphs.

2. The influence of temperature variation in adjusting total gain.

In semiconductor manufacturing resistors are made by various processes. These are diffusion, ion implantation, epitaxial, etc. And most of the semiconductor processes use

the physical characteristics of doped impurity carriers. For example the unit resistance of a diffused layer is given in equation 2.

$$R_{unit} = \frac{1}{q\mu_n N_D T} \quad (2)$$

Where, q is the electron charge; 1.6×10^{-19} coulomb

μ_n [$\text{cm}^2 / \text{V} \cdot \text{s}$] is the electron mobility

N_D [cm^{-3}] is the concentration of the donor

T is the thickness of the layer

In equation 2 is the function of temperature. Hence, the resistance value will vary depending on the temperature variation. Table 2 is a summary of resistor properties.

**Table 2. Summary of resistor Properties for different types of IC resistors
(Form Analysis and Design of Analog Integrated Circuits 3rd Ed.
By Gray and Meyer © 1993, John Wiley & Sons, Inc.)**

| Resistor type | Unit resistance | Absolute tolerance (%) | Matching tolerance (%) | Temperature coefficient |
|------------------|-----------------|------------------------|------------------------|-------------------------|
| Base diffused | 100 ~ 200 | ±20 | ±2 or ±0.2 | +1500 to +2000ppm/°C |
| Emitter diffused | 2 ~ 10 | ±20 | ±2 | +600ppm/°C |
| Ion implanted | 100 ~ 1000 | ±3 | ±1 or ±0.1 | +100ppm/°C |
| Base pinch | 2k ~ 10k | ±50 | ±10 | +2500ppm/°C |
| Epitaxial | 2k ~ 5k | ±30 | ±5 | +3000ppm/°C |
| Epitaxial pinch | 4k ~ 10k | ±50 | ±7 | +3000ppm/°C |
| Thin film | 0.1k ~ 2k | ±5 ~ ±20 | ±0.2 ~ ±2 | ±10 to ±200ppm/°C |

Let's concentrate on the temperature coefficient of table 2. In the case of a base pinch type resistor, if the resistor value is 10K then the resistor value at 100°C is calculated as shown below.

$$R_{100^\circ\text{C}} = R_{\text{STAN}} + (R_{\text{STAN}} \cdot T_{\text{COEFF}} \cdot \text{temp})$$

$$= 10\text{K} + (10\text{K} \cdot 2500 \times 10^{-6} \cdot 100) = 125\text{k}\Omega \quad (3)$$

In the case of a type A in table 1, the gain of the input stage is set to (R_2/R_{ext}) and only R_2 is subject to change when the temperature inside the IC is changed. If this R_2 is a base pinch type in table 2, the input stage gain A_{in} will increase 25% when the temperature inside the IC reaches 100°C.

3. Selection guide for a motor drive IC

Keeping these semiconductor characteristics in mind, users must note that the resistor value in the IC can be changed around 10~30% from the typical value when the IC is operated in hot conditions. Above all motor drive ICs in optical media applications include power devices that handle high current, which results in high power consumption and heat generation. Therefore, a more reliable way to adjust the input stage gain even though the temperature varies is recommended.

Let's examine type B.2 in table 1 and assume that $R_2 = R_1 = R_{\text{ext}} = 10\text{k}$ at 25°C, $R_1 = R_2 = 12\text{k}$ at 100°C.

$$25^{\circ}\text{C condition} \Rightarrow A_{in} = \frac{R_2}{R_1 + R_{ext}} = \frac{10k}{10k + 10k} = 0.5 \quad (4)$$

$$100^{\circ}\text{C condition} \Rightarrow A_{in} = \frac{R_2}{R_1 + R_{ext}} = \frac{12k}{12k + 10k} = 0.55 \quad (5)$$

$$100^{\circ}\text{C condition} \Rightarrow A_{in} = \frac{R_{ext2}}{R_{ext1} + R_{ext2}} \cdot \frac{R_2}{R_1}$$

$$= \frac{10k}{10k + 10k} \cdot \frac{12k}{12k} = 0.5 \quad (7)$$

The total gain difference between 100°C and 25°C is about 10%.

But if the user uses a type B.3 the situation dramatically changes there is no gain variance.

We summarized the advantages and disadvantages of the various types of input stage schemes in table 3. Table 4 is a summary of optical media related motor drive ICs manufactured by Fairchild in the context of the above classification.

$$25^{\circ}\text{C condition} \Rightarrow A_{in} = \frac{R_{ext2}}{R_{ext1} + R_{ext2}} \cdot \frac{R_2}{R_1}$$

$$= \frac{10k}{10k + 10k} \cdot \frac{10k}{10k} = 0.5 \quad (6)$$

Table 3. Summary of various input stages

| Func. Type | Total gain variation? (with Temp.) | Needed pin (DSP/MDI) | Gain attenuation | Extern. Comp. | Input stage gain(Ain) |
|---------------|---------------------------------------|-------------------------|--------------------------|---------------|--|
| Type A | Yes | 1/1 | Small gain Large gain | 1R | $\frac{R_2}{R_{ext}}$ |
| Type B.1 | No | 1/1 | Fixed | 0 | $\frac{R_2}{R_1}$ |
| Type B.2 | Yes | 1/1 | Small gain | 1R | $\frac{R_2}{R_{ext} + R_1}$ |
| Type B.3 | No | 1/2 | Small gain | 2R | $\frac{R_{ext2}}{R_{ext1} + R_{ext2}} \cdot \frac{R_2}{R_1}$ |
| Type C | Yes | 1/2 | Large gain | 1R | $\frac{R_2}{R_{ext} // R_1}$ |
| Type D | No | 1/2 | Small gain Large gain | 2R/0 | $\frac{R_{ext2}}{R_{ext1}}$ |
| Type E | No | 2/3 | Small gain Large gain | 4R/2C | Differential PWM |
| Type L | No | 3/3 | - | - | Logic loading |

Table 4. Classification of Fairchild Motor Drive ICs in Optical Media Applications

| Device | Channel | Input stage type (3-phase BLDC spindle included) | | | | | | |
|-------------|---------|--|--------|--------|-----|-----|-----|-----|
| | | CH1 | CH2 | CH3 | CH4 | CH5 | CH6 | CH8 |
| KA3014 * | | A | A | A | A | SPM | - | - |
| KA3017 * | | A | A | A | A | SPM | - | - |
| KA3012D | | E | E | E | E | - | - | - |
| KA3018D2 | | E | E | E | - | - | - | - |
| KA3021D | | C | L | B | C | - | - | - |
| KA3022D/D3 | | C | L | B | C | - | - | - |
| KA3027D2 | | E | E | B | L | - | - | - |
| KA3030D | | B | B (**) | B | B | L | L | - |
| KA3031 | | E | E (**) | B | B | L | L | - |
| KA3032 | | E | E (**) | E | E | L | - | - |
| KA9258BD | | C | C (**) | C | C | - | - | - |
| KA9259BD | | C | B (**) | B | C | L | - | - |
| KA9260D | | C | A (**) | A | C | L | - | - |
| FAN8000D | | C | C (**) | C | C | - | - | - |
| FAN8033 | | E | E | E (**) | E | L | L | - |
| FAN8001BD | | C | B (**) | B | C | L | - | - |
| FAN8024D/BD | | B | E | B | B | - | - | - |
| FAN8725 * | | D | D | D | D | D | SPM | - |
| FAN8002D2 | | B | B | - | - | - | - | - |
| FAN8007D | | B | B (**) | B | B | L | L | - |
| FAN8008 | | E | E | E | E | L | L | - |
| FAN8037 | | E | E | E | E | L | L | L |
| FAN8038B | | B | B | B | B | - | - | - |
| FAN8005D2 | | E | E | E | - | - | - | - |
| FAN8727 * | | A | A | A | A | SPM | - | - |
| FAN8004 | | E | E | E | E | L | - | - |
| FAN8034 | | E | E | E | E | E | L | - |
| FAN8039D3 | | A | B | B | A | L | - | - |
| FAN8006D3 | | E | B | E | E | - | - | - |

*: one chip optical media drive IC, **: DC motor drive channel for spindle motor, SPM: 3-phase BLDC driver

4. Conclusion

In a BTL type DC motor driver, the gain regulation is the most important factor. With this in mind, the users are encouraged to use a more stable method in gain adjustment, and to pay close attention to temperature issues in motor drive ICs.

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