

# How to Use the LM8342 VCOM Calibrator

## ABSTRACT

This application report explains how to use the LM8342 programmable VCOM calibrator device in AMLCD applications. It recommends circuit configurations for unipolar (AVDD) and bipolar ( $\pm AVDD$ ) displays, explains how to set the output voltage adjustment range, and how to add a positive or negative offset voltage. Worked examples are included for each case.

This application report is aimed at electronic design engineers who develop the electronics for AMLCDs such as those used in TVs, monitors, notebook or tablet PCs, and industrial and automotive applications.

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## 1 Introduction

The LM8342 VCOM calibrator device was developed at a time when almost all liquid crystal displays (LCDs) were unipolar. Unipolar displays use one positive  $AV_{DD}$  supply and a  $V_{COM}$  voltage just below half of  $AV_{DD}$ . For example,  $AV_{DD}$  might be 10 V and  $V_{COM}$  from 4.5 V to 5 V. Many modern displays, however, are bipolar, and use a  $\pm AV_{DD}$  supply and a  $V_{COM}$  voltage that is slightly negative. For example,  $AV_{DD}$  might be  $\pm 5$  V and  $V_{COM}$  from  $-0.5$  V to 0 V.

This application report explains how to use the LM8342 device to generate  $V_{COM}$  voltages for both unipolar and bipolar display applications. Note that all design examples in this application note use the E96 series of standard resistor values. The E48 or E24 resistor series can be used, but the  $V_{COM}$  range will be less accurately defined.

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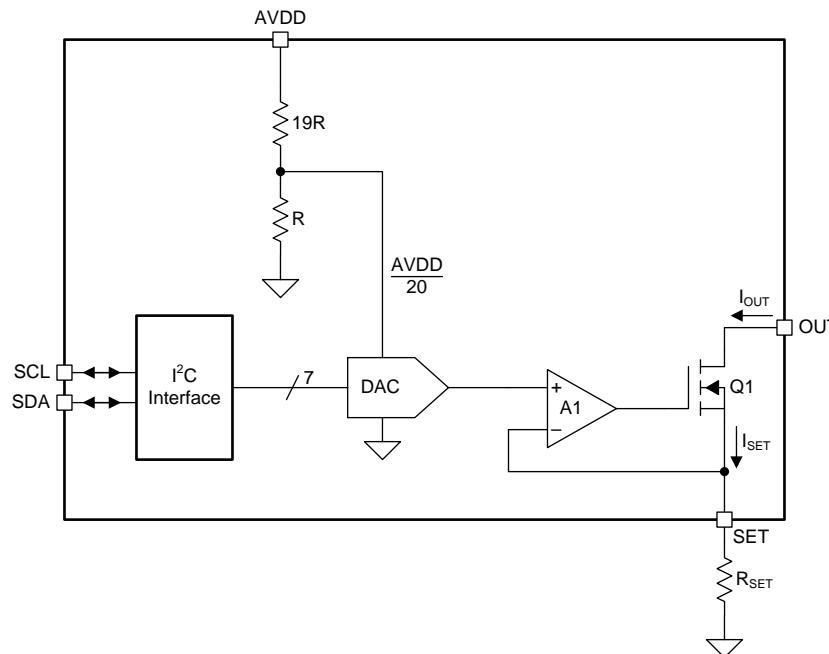
**NOTE:** Texas Instruments has developed a Microsoft® Excel® spreadsheet allowing easy calculation of the external component values for the LM8342. The spreadsheet is available free of charge from the [LM8342](#) product folder on ti.com.

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## 2 Principle of Operation

Figure 1 shows a simplified block diagram of the internal circuitry of the LM8342. The main functional blocks of this device are:

- A 7-bit digital-to-analog converter (DAC)
- An I<sup>2</sup>C interface
- An operational amplifier
- An NMOS output transistor



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**Figure 1. LM8342 Internal Block Diagram**

Amplifier A1 adjusts the gate voltage of transistor Q1 so that the voltage on the SET pin equals the output voltage of the DAC. When this happens:

$$V_{(\text{SET})} = V_{(\text{DAC})} = \left( \frac{V_{(\text{AVDD})}}{20} \right) \left( \frac{N + 1}{128} \right)$$

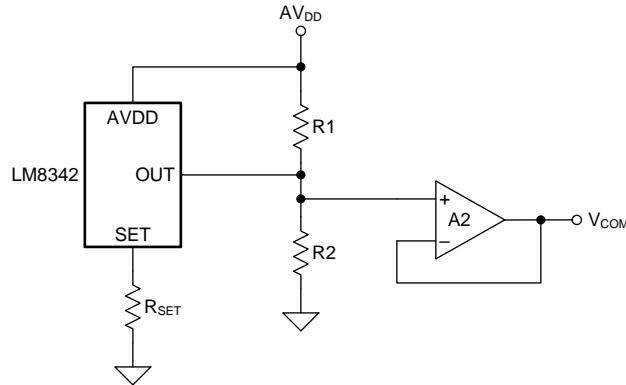
where

- N is the 7-bit digital input of the DAC
- $V_{(\text{DAC})}$  is the output voltage of the DAC
- $V_{(\text{SET})}$  is the voltage on the SET pin
- $V_{(\text{AVDD})}$  is the voltage on the AVDD pin

(1)

### 3 Using the LM8342 With Unipolar Displays

Figure 2 shows the recommended application circuit for unipolar display applications.



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**Figure 2. Recommended Application Circuit for Unipolar Displays**

An external resistor connected between the SET pin and ground sets the current flowing through Q1 so that:

$$I_{(OUT)} = \left( \frac{AV_{DD}}{20} \right) \left( \frac{N+1}{128} \right) \left( \frac{1}{R_{SET}} \right)$$

where

- $I_{(OUT)}$  is the current flowing into the OUT pin
- $R_{SET}$  is the resistance between the SET pin and ground

The minimum output current is generated when  $N = 0$  and is given by Equation 3:

$$I_{(OUT) \min} = \frac{AV_{DD}}{2560 \times R_{SET}} \quad (3)$$

The maximum output current is generated when  $N = 127$  and is given by Equation 4:

$$I_{(OUT) \max} = \frac{AV_{DD}}{20 \times R_{SET}} \quad (4)$$

The output current adjustment range is the difference between the minimum and maximum output currents and is:

$$\Delta I_{(OUT)} = \frac{127 \times AV_{DD}}{2560 \times R_{SET}} \quad (5)$$

The LM8342 is specified for full-scale output currents from 5  $\mu\text{A}$  to 100  $\mu\text{A}$ . For most applications TI recommends choosing a maximum value for  $I_{(OUT)}$  close to, but not greater than 100  $\mu\text{A}$ . To minimize current consumption, use a smaller value, but be aware that circuits that use smaller currents can be more susceptible to noise.

Rearranging Equation 4 provides:

$$R_{SET} = \frac{AV_{DD}}{20 \times I_{(OUT) \max}} \quad (6)$$

The maximum  $V_{\text{COM}}$  voltage of this circuit is generated with the minimum  $I_{\text{(OUT)}}$  and is given by Equation 7:

$$V_{\text{COM max}} = AV_{\text{DD}} \left( \frac{R2}{R1 + R2} \right) \left( 1 - \frac{R1}{2560 \times R_{\text{SET}}} \right) \quad (7)$$

The minimum  $V_{\text{COM}}$  voltage is generated with the maximum  $I_{\text{(OUT)}}$  and is given by Equation 8:

$$V_{\text{COM min}} = AV_{\text{DD}} \left( \frac{R2}{R1 + R2} \right) \left( 1 - \frac{R1}{20 \times R_{\text{SET}}} \right) \quad (8)$$

The  $V_{\text{COM}}$  adjustment range is the difference between the minimum and maximum values of  $V_{\text{COM}}$  and is given by Equation 9:

$$\Delta V_{\text{COM}} = \left( \frac{R1 \times R2}{R1 + R2} \right) \left( \frac{127 \times AV_{\text{DD}}}{2560 \times R_{\text{SET}}} \right) \quad (9)$$

Rearranging Equation 7, Equation 8, and Equation 9 provides Equation 10:

$$R1 = \frac{\Delta V_{\text{COM}} \times 2560 \times R_{\text{SET}}}{(127 \times V_{\text{COM max}}) + \Delta V_{\text{COM}}} \quad (10)$$

and

$$R2 = \frac{R1}{\left( \frac{127 \times R1 \times AV_{\text{DD}}}{\Delta V_{\text{COM}} \times 2560 \times R_{\text{SET}}} \right) - 1} \quad (11)$$

Equation 6, Equation 10, and Equation 11 are all that is needed to design the application circuit for a unipolar display.

### 3.1 Design Example 1 – Unipolar Display

Consider these design requirements:

- $AV_{\text{DD}} = 12 \text{ V}$
- $V_{\text{COM min}} = 5 \text{ V}$
- $V_{\text{COM max}} = 6 \text{ V}$
- $\Delta V_{\text{COM}} = 1 \text{ V}$

First, use Equation 6 to calculate the value of  $R_{\text{SET}}$ :

$$R_{\text{SET}} = \frac{12 \text{ V}}{20 \times 100 \times 10^{-6}} = 6 \text{ k}\Omega$$

The closest standard value greater than or equal to 6 k $\Omega$  is 6.04 k $\Omega$ , which will generate a full-scale current of 99.3  $\mu\text{A}$ .

Next, use Equation 10 to calculate the value of R1:

$$R1 = \frac{1 \times 2560 \times 6040}{(127 \times 6) + 1} = 20.27 \text{ k}\Omega$$

The standard value closest to 20.27 k $\Omega$  is 20.5 k $\Omega$ .

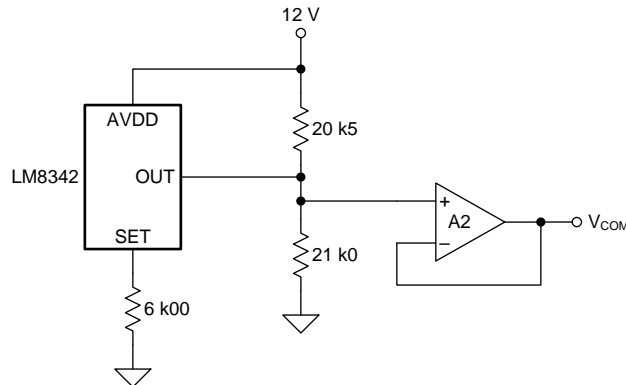
Finally, use Equation 11 to calculate the value of R2:

$$R2 = \frac{20500}{\left( \frac{127 \times 20500 \times 12}{1 \times 2560 \times 6040} \right) - 1} = 20.09 \text{ k}\Omega$$

The standard value closest to 20.09 k $\Omega$  is 21 k $\Omega$ .

Figure 3 shows the final circuit, which has the following performance:

- $V_{COMmin} = 5.042\text{ V}$
- $V_{COMmax} = 6.064\text{ V}$
- $\Delta V_{COM} = 1.022\text{ V}$



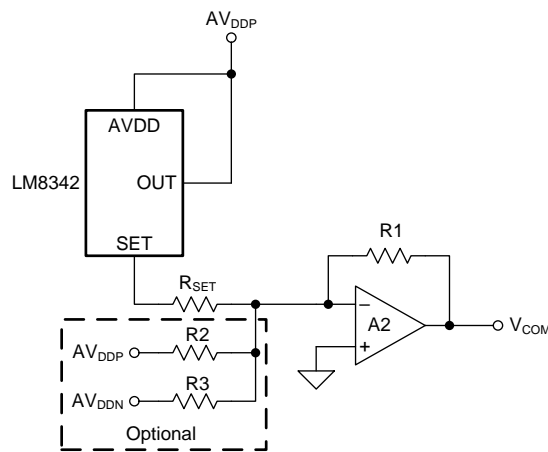
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Figure 3. Final Application Circuit for Design Example 1

#### 4 Using the LM8342 With Bipolar Displays

Figure 4 shows the application circuit TI recommends for bipolar displays. This circuit uses Q1 as a source follower, with its drain (the OUT pin) connected to the positive supply and the output voltage taken from the SET pin. The positive voltage on the SET pin is inverted and amplified by amplifier A2 to generate a negative  $V_{COM}$  voltage. Resistors R2 and R3 are optional:

- Include R2 and leave R3 open when adding a *negative* offset to the output voltage
- Include R3 and leave R2 open when adding a *positive* offset to the output voltage



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Figure 4. Recommended Application Circuit for Bipolar Displays

The circuit of Figure 4 generates an output voltage of:

$$V_{COM} = - \left( \frac{AV_{DDP}}{20 \times R_{SET}} \right) \left( \frac{N+1}{128} \right) R1 \tag{12}$$

The minimum (most negative) output voltage is:

$$V_{\text{COM min}} = - \left( \frac{AV_{\text{DDP}}}{20 \times R_{\text{SET}}} \right) R1 \quad (13)$$

The maximum (least negative) output voltage is:

$$V_{\text{COM max}} = - \left( \frac{AV_{\text{DDP}}}{2560 \times R_{\text{SET}}} \right) R1 \quad (14)$$

The output voltage adjustment range is:

$$\Delta V_{\text{COM}} = - \left( \frac{127 \times AV_{\text{DDP}}}{2560 \times R_{\text{SET}}} \right) R1 \quad (15)$$

Rearranging Equation 15 provides Equation 16:

$$R1 = \frac{\Delta V_{\text{COM}} \times 2560 \times R_{\text{SET}}}{127 \times AV_{\text{DDP}}} \quad (16)$$

#### 4.1 Design Example 2 – Bipolar Display Without Offset

Consider these design requirements:

- $AV_{\text{DD}} = \pm 5 \text{ V}$
- $V_{\text{COM max}} = 0 \text{ V}$
- $V_{\text{COM min}} = -0.45 \text{ V}$
- $\Delta V_{\text{COM}} = 0.45 \text{ V}$

First, choose a value for the full-scale output current. TI recommends a value close to, but not greater than, 100  $\mu\text{A}$ . Use Equation 6 to calculate the value of  $R_{\text{SET}}$ :

$$R_{\text{SET}} = \frac{5 \text{ V}}{20 \times 100 \times 10^{-6}} = 2.5 \text{ k}\Omega$$

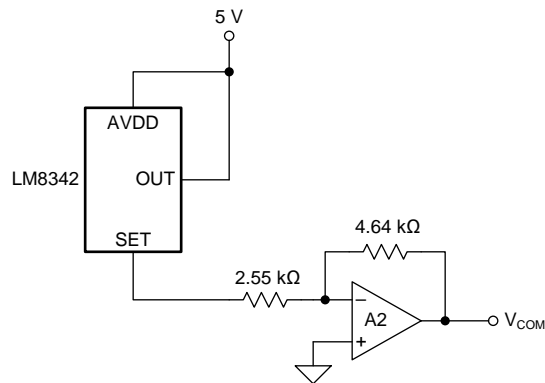
The standard value closest to, but not less than 2.5 k $\Omega$ , is 2.55 k $\Omega$ .

Next, use Equation 16 to calculate the value of R1.

$$R1 = \frac{0.45 \times 2560 \times 2550}{127 \times 5} = 4.626 \text{ k}\Omega$$

The standard value closest to 4.626 k $\Omega$  is 4.64 k $\Omega$ . With the standard values chosen, the performance of the final circuit is:

- $V_{\text{COM max}} = -0.004 \text{ V}$
- $V_{\text{COM min}} = -0.455 \text{ V}$
- $\Delta V_{\text{COM}} = 0.451 \text{ V}$



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**Figure 5. Final Application Circuit for Design Example 2**

Because the minimum output voltage is not zero but 1/128 of the full-scale value, the maximum output voltage of this configuration is never exactly zero. If the maximum  $V_{COM}$  voltage in the application must be zero, an additional resistor must be used to generate a positive offset voltage. To add a positive offset to the  $V_{COM}$  voltage, connect a resistor between the inverting input of the  $V_{COM}$  buffer and the  $AV_{DDN}$  supply. This will add an offset voltage of:

$$V_{COM\ offset} = -AV_{DDN} \times \frac{R1}{R3} \quad (17)$$

Rearranging Equation 17 produces Equation 18:

$$R3 = - \frac{R1 \times AV_{DDN}}{V_{COM\ offset}} \quad (18)$$

Similarly, for a negative offset, use Equation 19:

$$R2 = - \frac{R1 \times AV_{DDP}}{V_{COM\ offset}} \quad (19)$$

#### 4.2 Design Example 3 – Bipolar Display With Positive Offset

Consider these design requirements:

- $AV_{DD} = \pm 5.6\text{ V}$
- $V_{COM\ max} = 0.25\text{ V}$
- $V_{COM\ min} = -0.5\text{ V}$
- $\Delta V_{COM} = 0.75\text{ V}$

First, choose a value for the full-scale output current. TI recommends a value close to, but not greater than, 100  $\mu\text{A}$ . Use Equation 6 to calculate the value of  $R_{SET}$ :

$$R_{SET} = \frac{5.6\text{ V}}{20 \times 100 \times 10^{-6}} = 2.8\text{ k}\Omega$$

The value, 2.8 k $\Omega$  is a standard value, use that for  $R_{SET}$ .

Next, use Equation 16 to calculate the value of R1:

$$R1 = \frac{0.75 \times 2560 \times 2800}{127 \times 5.6} = 7.559\text{ k}\Omega$$

The standard value closest to 7.559 k $\Omega$  is 7.5 k $\Omega$ .

Next, use Equation 14 to calculate the maximum (least negative)  $V_{COM}$  voltage without R3:

$$V_{COM\ max} = -\left(\frac{5.6}{2560 \times 2800}\right)7500 = -5.9\ mV$$

R3, therefore, must add a positive offset of  $0.25\ V + 5.9\ mV = 256\ mV$ .

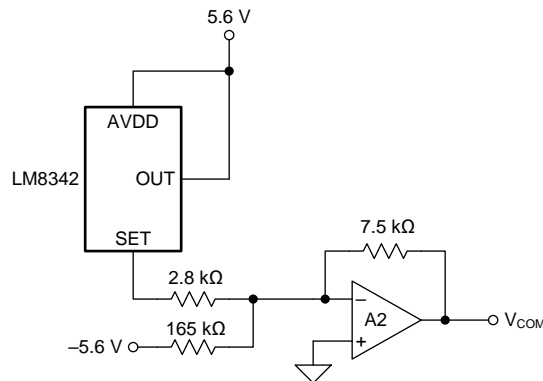
Finally, use Equation 18 to calculate the value of R3 needed to generate the desired offset voltage:

$$R3 = -\frac{7500(-5.6)}{0.256} = 164.1\ k\Omega$$

The standard value closest to 164.1 kΩ is 165 kΩ.

With the standard values chosen, the performance of the final circuit is:

- $V_{COM\ max} = 0.249\ V$
- $V_{COM\ min} = -0.496\ V$
- $\Delta V_{COM} = 0.745\ V$



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**Figure 6. Final Application Circuit for Design Example 3**

### 4.3 Design Example 4 – Bipolar Display With Negative Offset

Consider these design requirements:

- $AV_{DD} = \pm 6.3\ V$
- $V_{COM\ max} = -0.25\ V$
- $V_{COM\ min} = -0.75\ V$
- $\Delta V_{COM} = 0.5\ V$

To generate a negative offset voltage, an additional resistor R2 must be connected between the inverting input of the VCOM buffer and the  $AV_{DDP}$  supply.

First, choose a value for the full-scale output current. TI recommends a value close to, but not greater than, 100 μA. Use Equation 6 to calculate the value of  $R_{SET}$ :

$$R_{SET} = \frac{6.3}{20 \times 100 \times 10^{-6}} = 3.15\ k\Omega$$

The closest standard value greater than or equal to 3.15 kΩ is 3.16 kΩ, which will generate a full-scale current of 99.68 μA.

Next, use Equation 16 to calculate the value of R1:

$$R1 = \frac{0.5 \times 2560 \times 3160}{127 \times 6.3} = 5.055\ k\Omega$$

The standard value closest to 5.055 kΩ is 5.11 kΩ.



Next, use Equation 14 to calculate the maximum (least negative) VCOM voltage without R3:

$$V_{\text{COM max}} = -\left(\frac{6.3}{2560 \times 3150}\right) 5110 = -4 \text{ mV}$$

R2, therefore, must add a negative offset of  $0.25 \text{ V} - 4 \text{ mV} = -246 \text{ mV}$ .

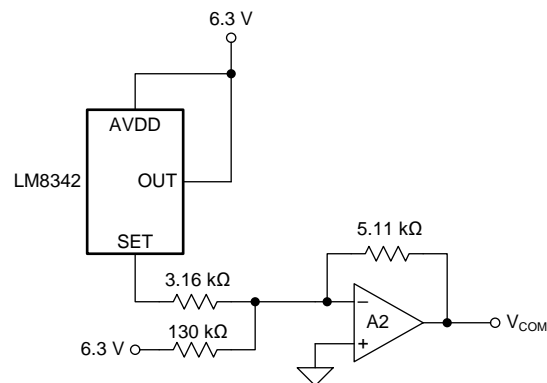
Finally, use Equation 19 to calculate the value of R2 needed to generate the desired offset voltage:

$$R2 = -\frac{5110 \times 6.3}{0.246} = 130.9 \text{ k}\Omega$$

The standard value closest to 130.9 kΩ is 130 kΩ.

With the standard values chosen, the performance of the final circuit is:

- $V_{\text{COM max}} = -0.252 \text{ V}$
- $V_{\text{COM min}} = -0.757 \text{ V}$
- $\Delta V_{\text{COM}} = 0.505 \text{ V}$



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**Figure 7. Final Application Circuit for Design Example 4**

## 5 Summary and Conclusion

The LM8342 is a 7-bit VCOM calibrator device that can be used in unipolar and bipolar applications. If the resistors in the application circuit are selected correctly, the VCOM adjustment range can be changed to suit any application.

## 6 References

- Texas Instruments, [LM8342 Programmable TFT VCOM Calibrator with Non-Volatile Memory Data Sheet](#)

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