AAT3190 Positive/Negative Bias Supply for CCD Camera Sensors

General Description
Typical CCD camera sensors require a positive and negative bias voltage of +15V and -8V, respectively, at load currents up to 10mA. This application requires good output regulation for these bias supply voltages. In addition, CCD camera sensors are noise sensitive and require very low input and output power supply ripple for the best circuit performance.

Application Problem
CCD camera sensor applications demand several different power supply requirements:
- Need to create high voltage positive and negative bias supplies from a single cell lithium-ion/polymer battery source. A single cell lithium-ion/polymer battery supply is typically 2.8V to 4.2V.
- The +/- bias supply is relatively low current with a typical range of up to 10mA per supply.
- CCD camera sensors are sensitive to power supply line noise and ripple. A +/- bias supply solution must minimize noise and ripple.
- Most bias supply solutions take some form of a switching regulator. The switching clock frequency of the bias supply device must be very high to minimize switching noise effects on the CCD sensor.

Application Solution
Use an AAT3190 to meet the requirements for CCD camera sensor bias supply applications:

The AAT3190 charge pump controller provides a regulated positive and negative voltage output. Two low-power charge pumps convert an input supply voltage ranging from 2.7V to 5.5V into two independent output voltages. The dual low-power charge pumps independently regulate a positive (V_{POS}) and a negative (V_{NEG}) output voltage. These outputs use external diode and capacitor multiplier stages (as many stages as required) to regulate output voltages up to ±25V. Built-in soft-start circuitry prevents excessive inrush current during start-up. A high switching frequency enables the use of small external capacitors and minimizes charge pump switching noise effects.

- Use five diode/capacitor stages to obtain the required +15V output for positive bias and use three diode/capacitor stages to obtain the required -8V output for the negative bias.
- Diode Selection Concerns:
  - Output load current capability
  - System efficiency
  - Diode stage voltage drop due to the diode forward voltage (V_F) vs. desired output voltage (V_{OUT})
- Capacitor Selection:
  - Use low ESR ceramic capacitors for low switching noise and ripple and maximizing circuit efficiency
  - High voltage rating based on the required output voltage level (V_{OUT})

Refer to the AAT3190 product datasheet for specific design equations and detailed applications instructions for creating +/- bias supply solutions with output levels different to those specified in this Application Note.
Design Procedure

The following steps show how to determine the circuit component values used in this application. For a detailed reference, these procedural steps are defined in the AAT3190 product datasheet.

The first step in the design procedure is to determine how many diode/capacitor stages will be required to achieve the desired positive and negative output voltage levels. The factors which govern this calculation are the diode forward voltage (\(V_F\)), the lowest input supply voltage (\(V_{IN\,(MIN)}\)), the desired positive output voltage level (\(V_{OP}\)), and the desired negative voltage output level (\(V_{ON}\)).

For this application:

\[ V_{IN\,(MIN)} = 3.2V \]

\[ V_F = 0.31V, \text{ based on a BAT54 diode for a forward current of } 4mA \]

\[ V_{OP} = +15V \]

\[ V_{ON} = -8V \]

Number of stages required for \(V_{OP}\):

\[
n_p = \frac{V_{OP} - V_{IN\,(MIN)}}{\frac{1}{2}(V_F)} = \frac{15V - 3.2V}{\frac{1}{2}(0.31V)} = 4.57
\]

- Round up to 5 stages.

Number of stages required for \(V_{ON}\):

\[
n_p = \frac{V_{ON}}{\frac{1}{2}(V_F) - V_{IN\,(MIN)}} = \frac{-8V}{\frac{1}{2}(0.31V) - 3.2V} = 3.01
\]

- Round to 3 stages.

The next step is to calculate the voltage feedback resistor divider component values. For the \(V_{OP}\) feedback, \(R4\) is preset at 6.02kΩ; for the \(V_{ON}\) feedback, \(R1\) is preset to 24.1kΩ. For the following calculations, \(V_{REF} = 1.2V\):
R3 calculation for the $V_{\text{OP}}$ feedback:

$$R3 = R4 \left( \frac{V_{\text{OP}}}{V_{\text{REF}}} - 1 \right) = 6.02\, \Omega \left( \frac{15V}{1.2V} - 1 \right) = 69.2\, \Omega$$

- Use 69.8k$\Omega$, the closest standard 1% tolerance resistor value.

R2 calculation for the $V_{\text{ON}}$ feedback:

$$R2 = \frac{V_{\text{ON}} \cdot R1}{-V_{\text{REF}}} = \frac{-8V \cdot 24.1\, \Omega}{-1.2V} = 160.7\, \Omega$$

- Use 162k$\Omega$, the closest standard 1% tolerance resistor value.

The output stages of the AAT3190 application circuit are relatively high voltage. The voltage rating of the ceramic flying capacitors ($C_{FLY}$) used for each stage must be sufficient to handle the high operating output voltage levels. The following calculation is used to determine the minimum voltage rating for the output stage capacitor selection. For these calculations, use the following given values: $V_{\text{IN(MAX)}} = 4.2V$, $V_F = 0.31V$, $n_P = 5$, and $n_N = 3$.

Minimum $V_{\text{OP}}$ capacitor voltage rating:

$$V_{\text{BULK}}(n) = (n + 1)V_{\text{IN(MAX)}} - 2(n)(V_F)$$

$$= (5 + 1)4.2V - 2(5)(0.31) = 22.1V$$

$$V_{\text{CFLY}}(n) = V_{\text{BULK}}(n) - V_F = 22.1V - 0.31V = 21.79V$$

- Select a low ESR ceramic capacitor with a voltage rating greater than 21.79V for the $V_{\text{OP}}$ charge pump circuit section.

Minimum $V_{\text{ON}}$ capacitor voltage rating:

$$V_{\text{BULK}}(n) = (-n)(V_{\text{IN(MAX)}}) + 2(n)(V_F)$$

$$= (-3)(4.2V) + 2(3)(0.31) = -10.74V$$

$$V_{\text{CFLY}}(n) = V_F - V_{\text{BULK}}(n)$$

$$= 0.31V - (-10.74V) = 11.05V$$

- Select a low ESR ceramic capacitor with a voltage rating greater than 11.05V for the $V_{\text{ON}}$ charge pump circuit section.
The final calculation for the AAT3190 +/- bias supply circuit is to verify whether the diodes selected for the charge pump stages have a sufficient reverse voltage characteristic to handle the highest input voltage level for the circuit. For a reasonable safety margin, the diode reverse voltage (\(V_R\)) should be at least 1.5X \(V_{IN(MAX)}\). For this application, \(V_{IN(MAX)} = 4.2V\).

Minimum diode \(V_R\) rating:

\[
V_{R(MIN)} = 1.5 \cdot V_{IN(MAX)} = 1.5 \cdot 4.2V = 6.3V
\]

- The BAT54 type diodes selected for this application have a 30V \(V_R\) specification. 30V > 6.3V, these diodes will be more than adequate for use in this circuit.
Measured AAT3190 CCD Camera Sensor Application Performance

Positive Output +V Characteristics

Efficiency vs. Output Current

Output Voltage vs. Output Current

Negative Output -V Characteristics

Efficiency vs. Output Current

Output Voltage vs. Output Current

+Input and Output Ripple Performance:

Channel 1: $V_{POS}$ = 18.0mV
Channel 2: $V_{NEG}$ = 10.2mV
Channel 3: $V_{IN}$ = 15.2mV
AAT3190 CCD Camera Sensor +/- Bias Supply Application Circuit

Notes:
2. C13-C24, C26: Taiyo Yuden EMK107BJ104MA, 0.1µF, 16V, X5R 0603 size, ceramic capacitor.