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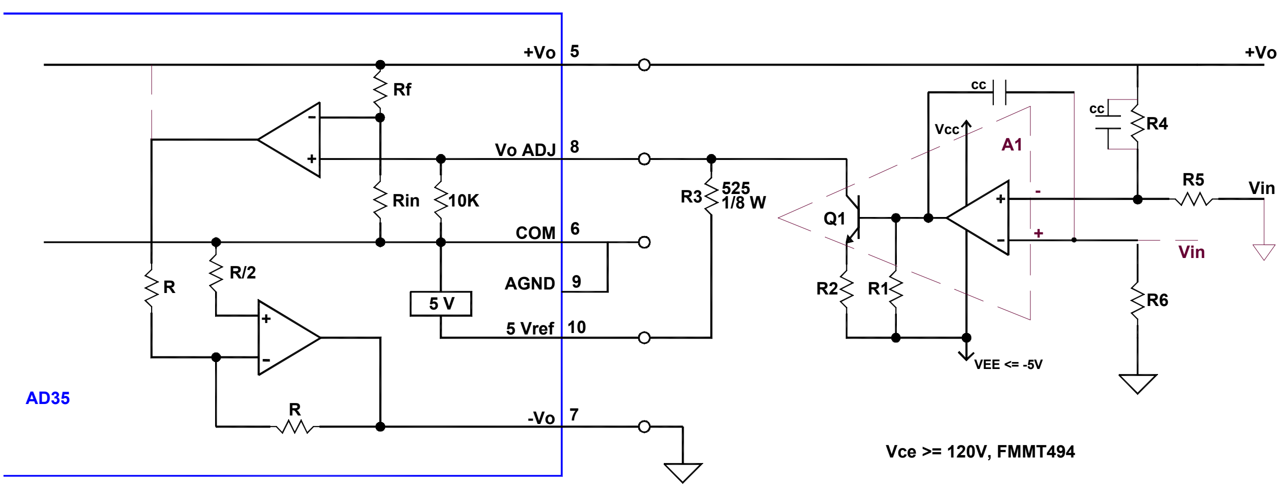
Application Note DC-021
DC/DC CONVERTERS

PROGRAMMING THE AD35 DC/DC CONVERTER

Referring to Figure 1A, amplifier A1 consists of a low voltage op amp and a high voltage NPN transistor Q1. By grounding the negative output of the AD35, the converter operates as a single positive output DC/DC from 0 to 200V.

A1 through Q1 sets the V_O ADJ voltage of AD35. At turn on, the $5V_{REF}$ of the converter through R3 will set the output to 200V if A1 is not powered up ($V_{CC} = V_{EE} = 0$). When V_{CC} and V_{EE} of A1 is turned on at the same time, the AD35 is turned on and A1 takes over the control of the output of AD35. A1 will wait for a few milliseconds due to the turn on delay and soft start of the AD35.

It must be pointed out that the AD35 operates as a non-inverting amplifier, i.e. V_{OUT} increases as V_O ADJ increases or, more specifically, V_O ADJ increases with respect to V_O COM. Therefore an inverting amplifier can be used to control the AD35. In this configuration, the voltage gain of the linear block is given by the feedback resistor network R4 and R5. The linear block of A1 plus AD35 can be viewed as a single positive supply, adjustable amplifier that can be controlled through a positive input when V_{IN} is applied on the non-inverting input of A1 (the negative input of the op amp inside A1) or through a negative V_{IN} when the positive input of A1 is grounded through R6 and -V_{IN} is applied at the open end of R5. As can be seen in Figure 1A, R1 and R2 are pull-down resistors to V_{EE}. Depending on the voltage used for V_{EE}, select R2 such that V_C of Q1 is a few millivolts (mV) negative when V_O = 0V and Q1 is at saturation. The collector current of Q1 is the current through R3 required to set V_O ADJ to 0V.



1. Vo = -R4/R5 * Vin with the non-inverting input of A1 grounded through R6
   Vin <= 0V
2. Vo = (1 + R4/R5) * Vin with R5 grounded and Vin applied on the positive input of A1
   Vin >= 0V
3. R3 is required for start-up

FIGURE 1A

5V/R3 = I <= 9.5mA

and

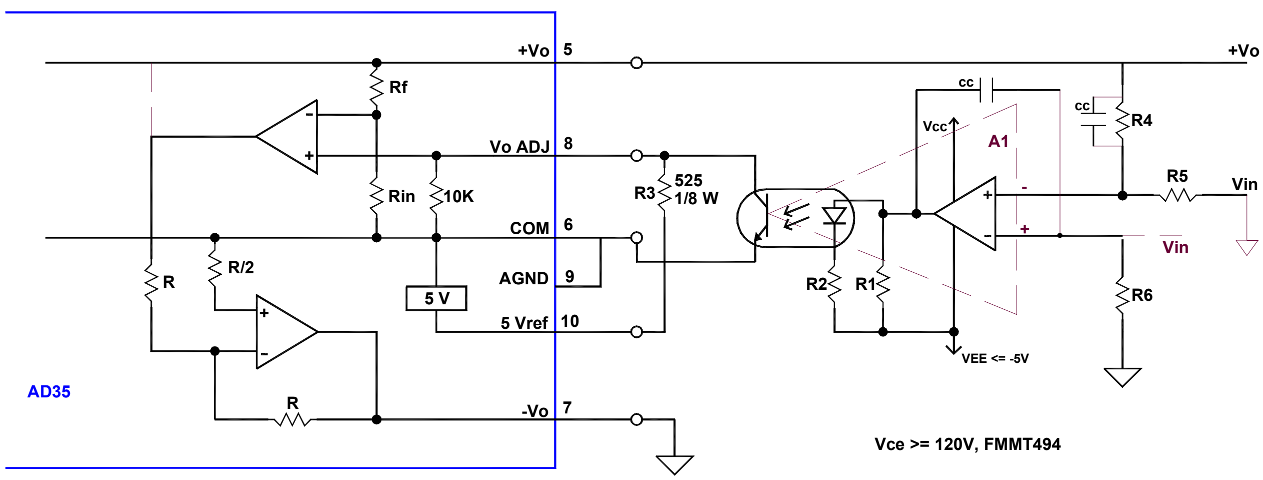
V_{CE} + I*R^2 = V_{EE}

For V_{CE} of Q1 = 100mV, V_{EE} = -5V, I = 9.6mA

R2 = (5 – 0.1)/9.6 = 510Ω

R1 is required only if the output voltage of the selected amplifier inside A1 cannot go rail to rail such as LM358, MC34072 and others. R1 will pull the output to V_{EE} forcing Q1 off and the collector current to zero when +V_O is set for the V_O maximum of 200V.

A photo coupler can also be used as the output stage of A1 to replace Q1 (see Figure 1B). The collector of the phototransistor is connected to V_O ADJ (Pin 8 of AD35) while the photodiode will be connected as is to the emitter of Q1 (between R2 cathode and the output of the OPAM inside A1 anode). The accuracy of the linear block depends only on the accuracy of V_{IN} and its feedback network R4 and R5.



1. Vo = -R4/R5 * Vin with the non-inverting input of A1 grounded through R6
   Vin <= 0V

2. Vo = (1 + R4/R5) * Vin with R5 grounded and Vin applied on the positive input of A1
   Vin >= 0V

3. R3 is required for start-up

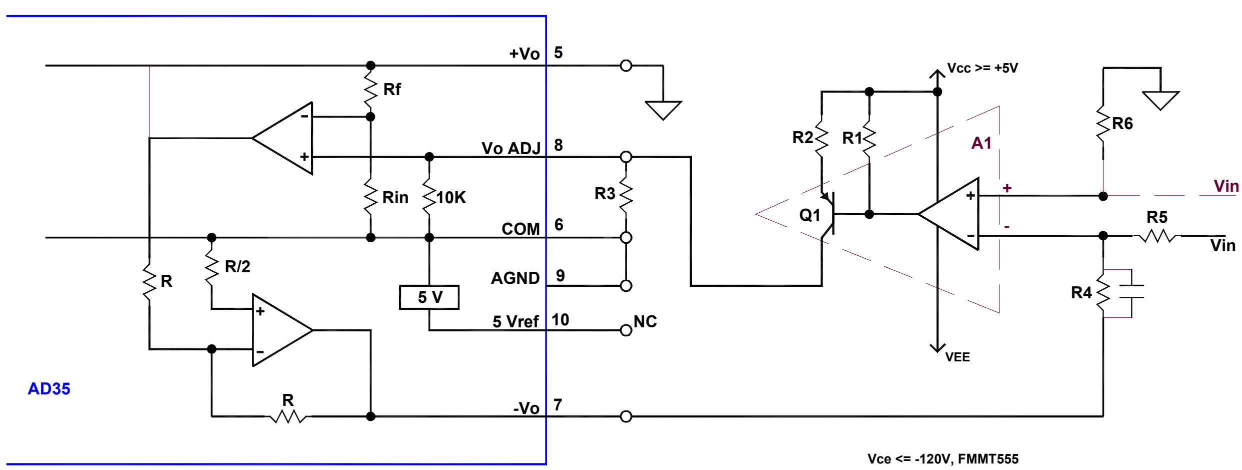
FIGURE 1B

Referring to Figure 2, the AD35 with A1 is configured as a single negative, adjustable output converter. The positive output (Pin 5) is grounded and the rest of the output pins are floating.

At turn on, if A1 is not powered up, the output of AD35 will be zero volts (0V). The AD35 block behaves as an inverting amplifier in Figure 2 (i.e. $-V_O$ increases as V_O ADJ Pin 8 becomes more positive with respect to COM Pin 6 or as the collector current through Q1 increases).

Given that the AD35 block acts as an inverting amplifier and Q1 also acts as an inverting amplifier, the input pin polarity of A1, inverting and non-inverting inputs, and the op amp inside A1 have the same polarity, then the negative output V_O at Pin 7 is given as: $-V_O = (R4/R5)V_{IN}$ with the non-inverting input grounded through R6 and $V_{IN} >= 0$. With R5 connected to ground and V_{IN} applied at the non-inverting input, $V_O = (1+(R4/R5))V_{IN}$ for $V_{IN} <= 0$.

R3 in Figure 2 can be connected between V_O ADJ Pin 8 and COM (in parallel with 10K) when higher current through Q1 is required to increase noise immunity or resolution. R1 performs the same function as described above in Figure 1A. If a photocoupler is used (as it is shown in Figure 1B) to replaced Q1 in Figure 2, the collector of the phototransistor is connected at the $5V_{REF}$ Pin 10 and its emitter at V_O ADJ Pin 8. The photodiode of the optocoupler will replace the emitter to base function of Q1 in Figure 2. A dual operational amplifier and two bipolar high voltage transistors can be used to design a bipolar adjustable 0 to ±200V voltage source, which can be controlled from a single input voltage source.



1. Vo = -R4/R5 * Vin   Vin >= 0V, R6 installed

2. Vo = (1 + R4/R5) * Vin   Vin <= 0V   R5 grounded and Vin applied to the non-inverting input of A1

FIGURE 2

Programming the AD35 with a Current Source

Referring to Figure 3, a current source with open circuit protection is used to program the positive output voltage of the AD35. The D/A converter through A1 and Q1 sets the current through RCS, which is given by: $I = (V_{D/A})/R_{CS}$.

The open circuit protection consists of A2 with its input network and Q2. When S1 is set to the off position, V_B drops to 0V, comparator A2 turns Q2 on setting the positive input of A1 to 0V. Without the open circuit protection and if V_{DS} is 0V, the output of A1 will go to its maximum output voltage, turn on Q1 and stay at its maximum V_{OUT} until V_{DS} is connected to a voltage source or S1 is set to the on position.

As soon as $V_{DS} > 0$, Q1 will be fully on and the only current limiting resistor will be R_{CS}. Because A1 does not respond instantaneously, the unlimited current through R_{CS} may destroy R_{CS} and force the V_O ADJ voltage at Pin 8 to momentarily go to zero or even cause the output of the AD35 to become unstable.

The voltage divider for V_B must be very high (in the order of MΩ) to allow a very small amount of current through it. To calculate the current I versus V_O from the AD35 data sheet:

#1 $V_O = 42{*}V_O$ ADJ

and from Figure 1A,

#2 V_O ADJ $= 5V – R3{*}I$ (if we neglect the 10kΩ)

#3 $V_O = 42(5 – R3{*}I) = 210 – 42R3{*}I$

#4 $I = (V_O – 210)/(42{*}R3) = (V_O – 210)/22050$

where V_O in Eq. 4 is the required value for V_O (Pin 5 AD35).

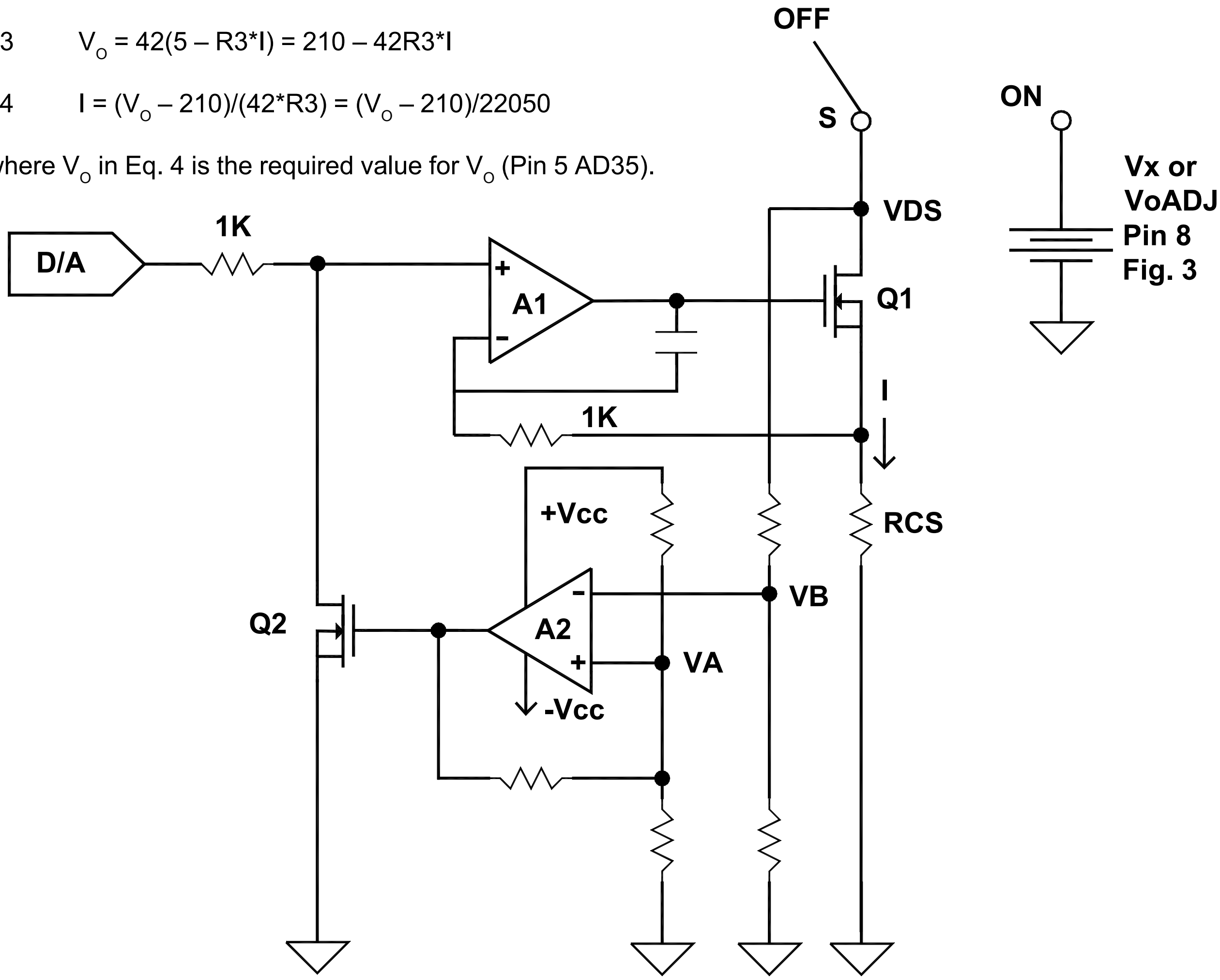


FIGURE 3

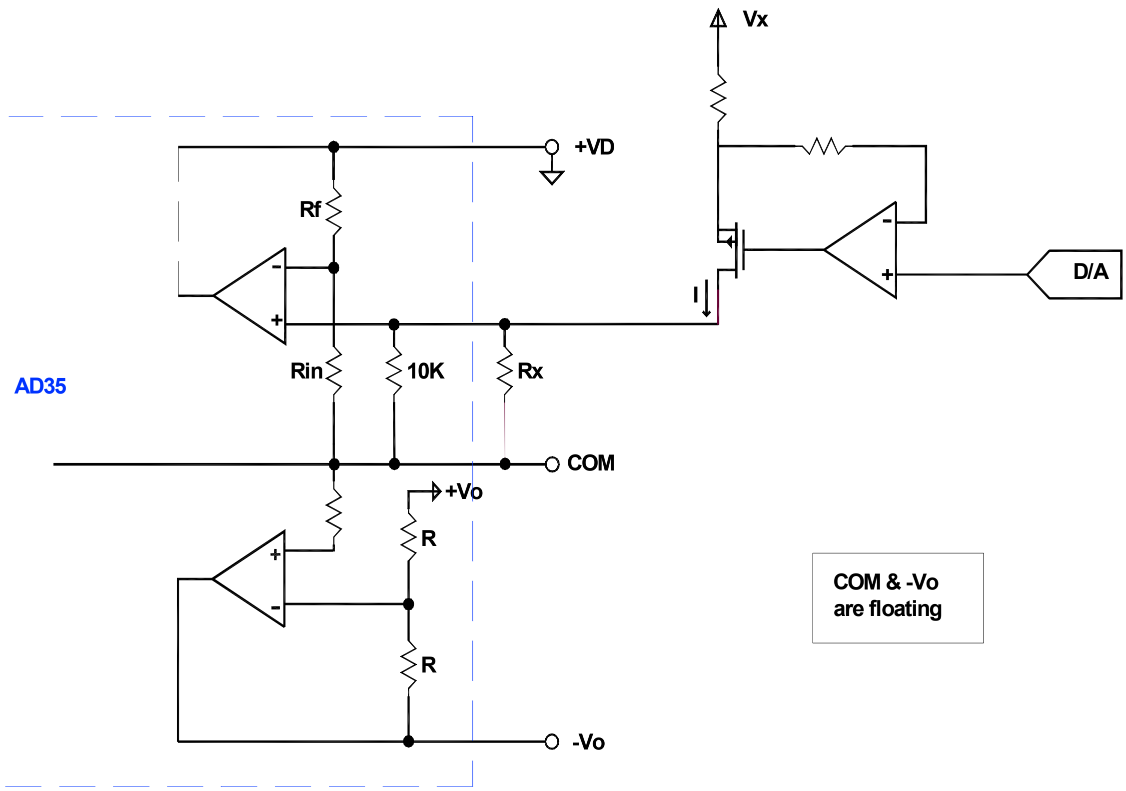
Referring to Figure 4, the AD35 is connected for a negative output. The current source consists of A1, a P-channel high-voltage MOSFET and a stable voltage source V_X. From the data sheet, V_O is given by:

#1 $V_O = 42 * V_O$ ADJ

#2 V_O ADJ = 10*I or $(10||R_X)$*I if R_X is installed

$I = (V_X - V_{D/A})/R_{CS}$

If an open circuit protection is needed, the same approach used in Figure 2 will force $V_{D/A}$ to V_X, thus the current through R_{CS} will be zero.



-Vo = 2 * 21 * I(10||Rx) **-Vo = 0 if I = 0**

I = 0 if Vx = Vd/a Vx >> 0V

NOTE: +5V reference is not used

FIGURE 4