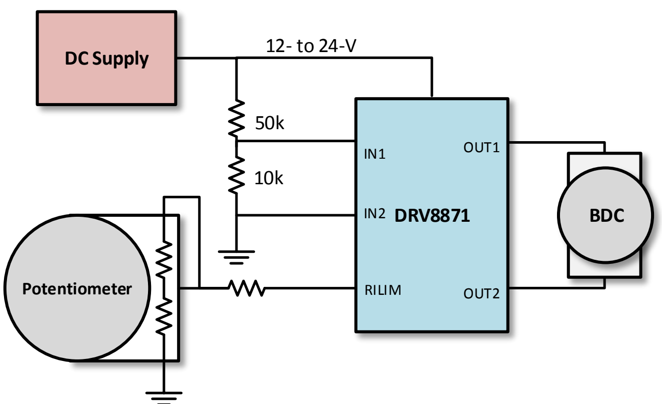
TIDA-00786 Ultra Small Brushed DC Motor Current Regulation TI Reference Design

Design Overview

TIDA-00786 is a small footprint brushed DC motor controller that has a fixed 100% duty-cycle speed input and variable current regulation. The DRV8871's integrated current sensing feature allows the design to utilize a standard potentiometer allowing the user to vary the current limiting level quickly between a range of motors that can be powered by a 12- to 24-V input.

Design Resources

TIDA-00786	Design Folder
DRV8871	Product Folder

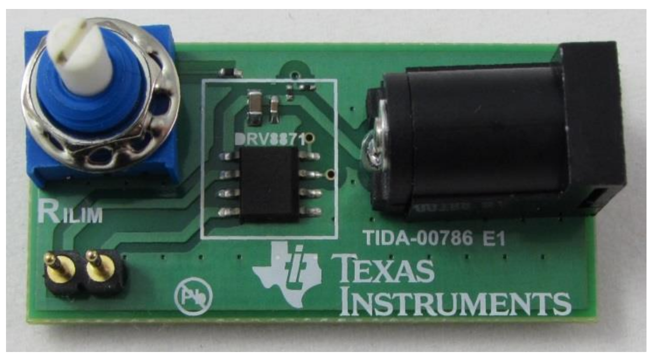


Design Features

- 12- to 24-V operation with up to 3.6 Amps continuous motor current
- fixed speed input at 100% duty-cycle
- onboard 100-mill header for quick change of motor connections
- DC Barrel plug allows for universal connections from different commercial power supplies
- durable potentiometer equipped to handle extended use
- internal current regulation allows for extremely small footprint
- variability of R_{ILIM} reduces test time for determining proper end application current regulation level

Featured Applications

- Printers
- Appliances
- Industrial Equipment
- Other Mechatronic Applications



1. Introduction:

Typical bi-directional brushed DC motor control schemes require a switching bridge, some form of gate drive, and a speed / direction interface. The DRV8871 packages all of these necessities into one 8-pin HSOP package while also including internal current regulation that only requires a small low-power external resistor. This reference design implements a large and durable potentiometer intended to allow the user to set a variety of current regulation levels in order to fine tune the value at which current regulation should be set in an end application of the DRV8871. With this intention in mind the driver is always kept at a 100% duty-cycle output in order to draw the largest possible current through the motor during startup and normal steady-state operation.

2. Integrated Current Sensing

Utilizing integrated current sensing with the DRV8871 means this design doesn't require a large external sense resistor to measure the current running through a brushed DC Motor. The level at which current sensing will begin within the device can be set using a small low power external resistor connected to the I_{LIM} pin of the driver. This allows for board layout of the device to be extremely small and not require any extra high current traces used for sensing applications. The minimum value for the external resistor used with this device is 15 kΩ as stated in the data sheet, so this design uses a 200 kΩ potentiometer in series with a 15 kΩ resistor. Using **Equation 1** below, the maximum and minimum values of current regulation possible with the device are:

I_{LIM_MAX} = 64 (k) V / (15 kΩ) = 4.27 A **Equation 1**
I_{LIM_MIN} = 64 (k) V / (215 kΩ) = 298 mA **Equation 1**

The variability of this design allows the user to set the current limiting at any value between the maximum and minimum listed above. During operation of the DRV8871 when the current measured by the driver running through the motor has reached the I_{LIM} value the device enforces a period of slow decay for approximately 25 µs by enabling both low side FETs to reduce motor winding current.

3. Voltage Droop

System bulk capacitance is a crucial part of board layout with motor driver circuits because of the bulk capacitances ability to supply charge to the H-bridge when the power supply cannot react fast enough. Pulling charge from these capacitors for a short period of time is normal to the devices operation but once the charge has been depleted from the capacitors and the current draw by the motor is still above the rated current limit of the power supply the system can no longer sustain the V_M voltage rail causing it to drop below the rated value. This effect can cause other system devices to shut off or be damaged due to the sudden lack of voltage. An example of the voltage sag in a system with improper current limiting and excessive voltage drooping is shown in **Figure 1** below.

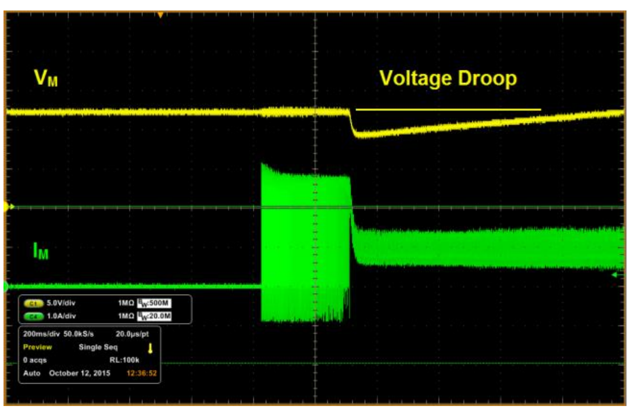


Figure 1. V_M Droop Without Current Limiting

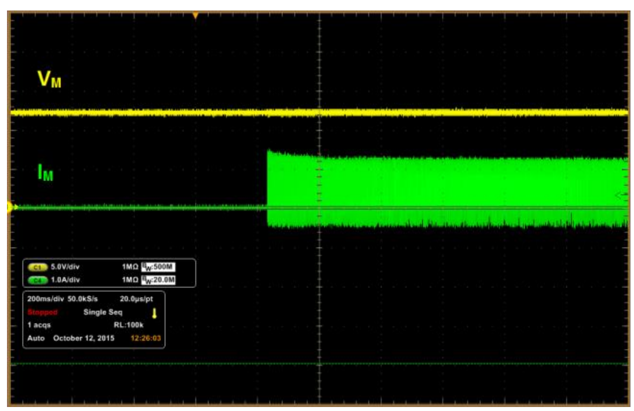


Figure 2. V_M Stable with Current Limiting

By using the adjustable current limiting on this reference design a current regulation level was set below the rated current of the power supply insuring that V_M will stay at a stable value during motor startup. This is illustrated in **Figure 2** by adjusting current regulation to a lower level than previously allowed in **Figure 1** causing startup current to be limited and V_M being held at a stable 12 V.

4. Startup Current

DC brushed motors with low inductance and DC resistance can cause large amounts of current draw when the motor begins spinning. This is due to the fact that for a brief period of time the equivalent circuit for the brushed motor is just the DC resistance of the coil divided by the applied supply voltage as shown in **Equation 2** below:

$$I_{START} = V_{SUPPLY} / R_{WINDING} \qquad \textbf{Equation 2}$$

This results in a large current being drawn from the supply in proportion to what the average unloaded steady-state current would be for the motor. This is because once the motor begins spinning a back electromotive force (back-EMF) is generated by the brushes of the motor cutting the magnetic field lines of the armature as the rotor begins spinning causing a voltage to be present in the armature coil. This back-EMF voltage is opposed to the supplied voltage to the motor, so the actual applied motor current while the motor is spinning can be described using **Equation 3** below:

$$I_{STEADY\text{-}STATE} = (V_{SUPPLY} - V_{BEMF}) / R_{WINDING} \qquad \textbf{Equation 3}$$

For a motor with a low value for $R_{WINDING}$ the startup current can be very large in proportion to the steady-state current required to keep the motor running. The scenario were the motor startup current is significantly larger than the required steady-state current is where current limiting with the DRV8871 can be utilized to start these types of motors in applications where the power supply may not be able to meet the required startup current demand.

5. Maxon Motor RE 30 310007

The Maxon RE 30 310007 brushed DC motor has a terminal resistance of 611 mΩ and terminal inductance of 119 µH with a nominal operating voltage of 24 V. Using **Equation 4** above the starting supply current can be approximated as:

$$I_{START} = V_{SUPPLY} / R_{WINDING} = 24\ V / 611\ m\Omega = 39.279\ A \qquad \textbf{Equation 4}$$

If the motor were held in a stall state for long enough this is the value of current that would be pulled from the power supply. In practice the motor begins spinning before this current value is reached so the actual current pulled from the power supply will be a lower value than that calculated above. This is exemplified in **Figure 3** below showing the startup current peak from this motor.

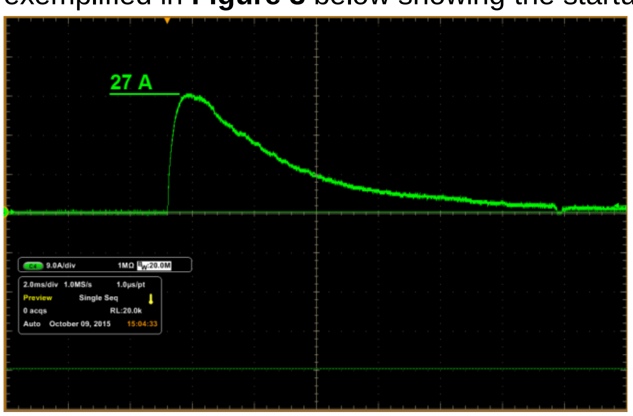


Figure 3. Maxon RE 30 310007 Startup Current

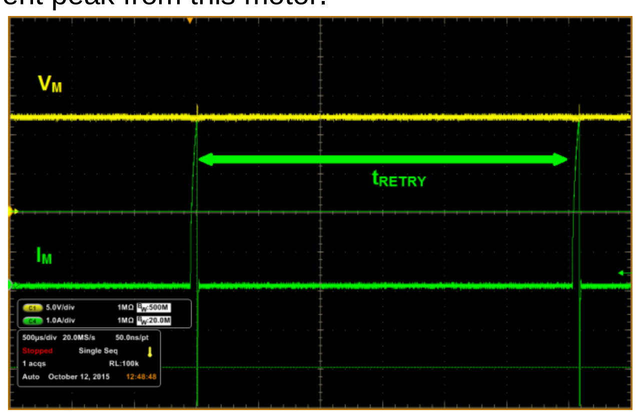


Figure 4. OCL t_{RETRY} interval

If the DRV8871 were used in an application to drive this motor but the current limiting functionality was not properly utilized the device would not be able to drive the amount of current being pulled through the internal H-bridge and would trigger an Over Current Limit (OCL) event. During this period the device will not allow current to flow through the bridge and shuts off the internal FETs for a period of 3 ms as shown in **Figure 4** above. This condition stops the DRV8871 from driving more current than the internal MOSFETs and current regulation technology can safely handle.

By adjusting the potentiometer on this reference design to a position where current is being regulated at 2.6 A the Maxon motor still has enough current to begin spinning without pulling more current than the device can supply. Current regulation used to start the Maxon motor is shown in **Figure 5** below.

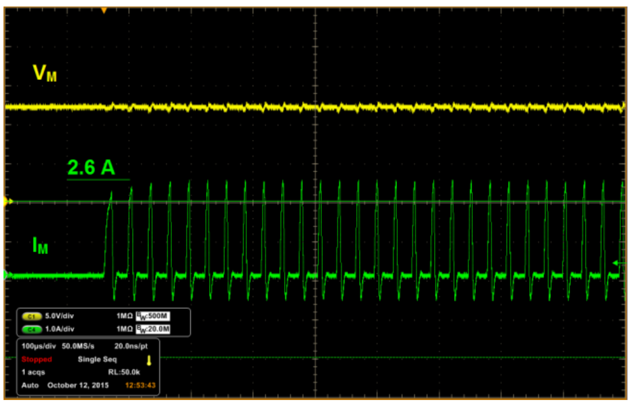


Figure 5. 2.6 A Current Regulation

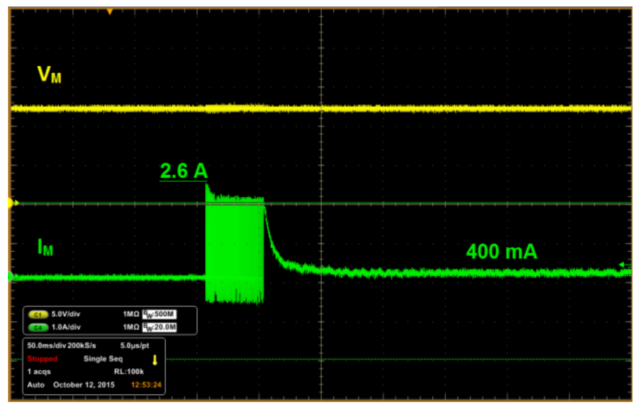
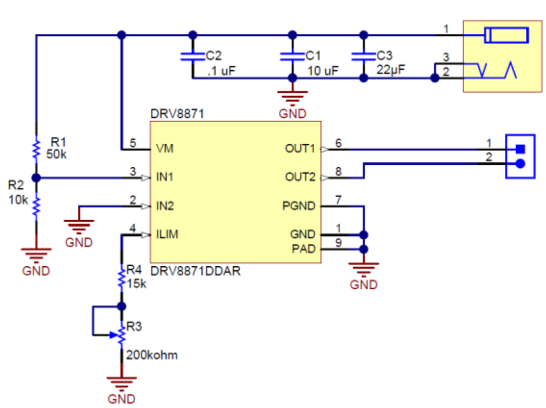


Figure 6. Startup and Steady State Current

By limiting the current during the above startup condition the reference design can now supply enough current to successfully start the Maxon motor. Once the motor has started turning the actual steady state current of the motor is significantly less than that which is required to start the motor. In the case of this Maxon motor the starting current is limited to 2.6 A but the actual unloaded steady state current is only 400 mA, which is significantly less than what was required to start the motor. The startup state compared to steady state current is illustrated in **Figure 6** above.

6. System Schematic



The schematic for this device is incredibly simple because of the integrated current sensing and integrated H-bridge. There is only a need for several small discrete components used as bulk capacitance, a voltage divider to control the 100% duty-cycle input, and the potentiometer + series resistor used for the variable current limiting. If a specific motor is already chosen the 200 kΩ potentiometer and 15 kΩ resistor could be replaced with one small footprint resistor calculated exactly for this application. The DC barrel plug could also be replaced if the user has no need to demo current regulation with a commercially available wall adaptor power supply used with laptops and other consumer devices.

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