

## A Guide to understanding L6470, L6480, and powerSTEP01 output voltage levels

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Main components	
L6470	Fully integrated microstepping motor driver with motion engine and SPI
L6480	Fully integrated microstepping motor controller with motion engine and SPI
powerSTEP01	System-in-package integrating microstepping controller and 10 A power MOSFETs

### Purpose and benefits

Since the L6470, L6480, and the powerSTEP01 are voltage mode devices, in order to understand their operation, it is essential to understand the factors which control the magnitude of their sinusoidal output voltages. The expressions, which describe the output voltage magnitude for the various operating modes of each device, are given in the formulas below. There are seven distinct operating modes during normal operation, also described.

### Output Voltage Calculations

If a stepper motor were to be operated in voltage mode only at very low speeds, then we would only need Ohm's law and the motor coil resistance to determine the magnitude of voltage required to achieve a desired current level, and that voltage would be constant for a constant current. As motor speed increases, however, both motor back electro-motive force (bemf) and reactance contribute to "steal" voltage away from the motor. To compensate for this, the L6470, L6480, and powerSTEP01 will increase output voltage as a direct function of operating speed. While bemf has an effect essentially from zero speed, inductive reactance is generally only relevant beyond some threshold speed which is associated with the corner frequency of the R-L circuit. Because of this, the voltage compensation provided by the L6470, L6480, or powerSTEP01 is a piecewise-linear curve employing two linear slopes. Both slopes and the intercept speed where the system transitions from one slope to the other are user adjustable.

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Please note, in formulas 2, 3, and 4, the terms  $(\text{SPEED}/250)$  and  $(\text{ST\_SLP}/256)$ . The register setting ST\_SLP controls the slope of the "volts per HZ" type of bEMF compensation term in effect when operating below the intercept speed. One way to interpret ST\_SLP is that it represents the amount of "boost" that is applied when the speed reaches 250 steps/second. The term  $(\text{ST\_SLP}/256)$  simply identifies the intrinsic 8 bit scaling of the term, where 256 would represent 1.0 or full boost. For example, if ST\_SLP is set to 128, then the addition from the boost term will be  $\frac{1}{2}$   $(128/256)$  of  $V_s$  (at 250 steps/second). At speeds above or below 250 steps/second, the boost will be proportionately above or below  $\frac{1}{2}$  of  $V_s$ . Of course, the peak voltage output will be limited or clipped at  $V_s$ . In summary, when operating below the intercept speed, the output voltage magnitude is made up of two components. A fixed component (determined by KVAL\_HOLD, KVAL\_RUN, KVAL\_ACC, or KVAL\_DEC as appropriate) and a variable term which is directly proportional to motor speed.

The output voltage magnitude when operating above the intercept speed is similar in that the magnitude is again made up of two terms, one constant and one variable. In formulas 5, 6, and 7, the constant term is the one enclosed in square brackets. This term represents the output voltage expressed in formulas 2, 3, or 4 just up to the point where the motor attains intercept speed. Going beyond intercept speed, the variable term is quite similar to the variable term in effect below intercept speed except that the contribution is now directly proportional to DELTA\_SPEED, which is the amount by which motor speed exceeds the intercept speed, and the slope of this variable term can be determined by one of two possible slopes. Either FN\_SLP\_ACC (actually in effect when either accelerating or running at constant speed) or FN\_SLP\_DEC (in effect when decelerating) will be used as appropriate.

The following formulas apply equally to the L6470, L6480 and the powerSTEP01 when operating in voltage mode. The formulas are divided into the 7 distinct operating modes.

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1. Motor stopped:

$$V_p = V_s * (KVAL\_HOLD / 256)$$

Note:  $V_p$  is the peak sinusoidal value and will only be realized if the electrical angle at stop is 0, 90, 180, or 270 degrees and will be positive or negative at  $V_a$  or  $V_b$  according to the electrical angle.

2. Constant speed below intersect speed:

$$V_p = V_s (KVAL\_RUN/256) + V_s(SPEED/250)(ST\_SLP/256)$$

3. Accelerating below intersect speed:

$$V_p = V_s (KVAL\_ACC/256) + V_s(SPEED/250)(ST\_SLP/256)$$

4. Decelerating below intersect speed:

$$V_p = V_s (KVAL\_DEC/256) + V_s(SPEED/250)(ST\_SLP/256)$$

5. Constant speed above intersect speed:

$$V_p = [V_s (KVAL\_RUN/256) + V_s(INT\_SPEED/250)(ST\_SLP/256)] + V_s(DELT\_SPEED/250)(FN\_SLP\_ACC/256)$$

6. Accelerating above intersect speed:

$$V_p = [V_s (KVAL\_ACC/256) + V_s(INT\_SPEED/250)(ST\_SLP/256)] + V_s(DELT\_SPEED/250)(FN\_SLP\_ACC/256)$$

7. Decelerating above intersect speed:

$$V_p = [V_s (KVAL\_DEC/256) + V_s(INT\_SPEED/250)(ST\_SLP/256)] + V_s(DELT\_SPEED/250)(FN\_SLP\_DEC/256)$$

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Notes:

1.  $V_p$  is the peak sinusoidal output voltage.
2.  $V_s$  is the motor supply voltage in volts.
3. SPEED is motor speed in full steps per second.
4. INT\_SPEED is the intersect speed in steps/second.
5. DELTA\_SPEED is the speed in steps/second in excess of the INT\_SPEED, (SPEED – INT\_SPEED).
6. The effect of Low Speed Optimization is not included in the formulas. This contribution is zero once the motor speed exceeds MIN\_SPEED.
7. If the supply voltage compensation is enabled, the  $V_p$  (peak sinusoidal output voltage) expressed in the seven main operating states is further multiplied by a factor of:  
 $(1.65/V_{adc})(1 + K_{therm}/32)$  where  $V_{adc}$  is the voltage present at the ADC input pin and  $K_{Therm}$  ranges from 0 to 15.

$V_{adc}$  is derived from the supply voltage and calibrated to present 1.65 volts with supply at nominal.

## Support material

Documentation
Datasheet, L6470, Fully integrated microstepping motor driver with motion engine and SPI
Datasheet, L6480, Fully integrated microstepping motor controller with motion engine and SPI
Datasheet, powerSTEP01, System-in-package integrating microstepping controller and 10 A power MOSFETs

## Revision history

Date	Version	Changes
14-Jul-2016	1	Initial release

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