

Scaling of the Analog Outputs for Common Motor Information

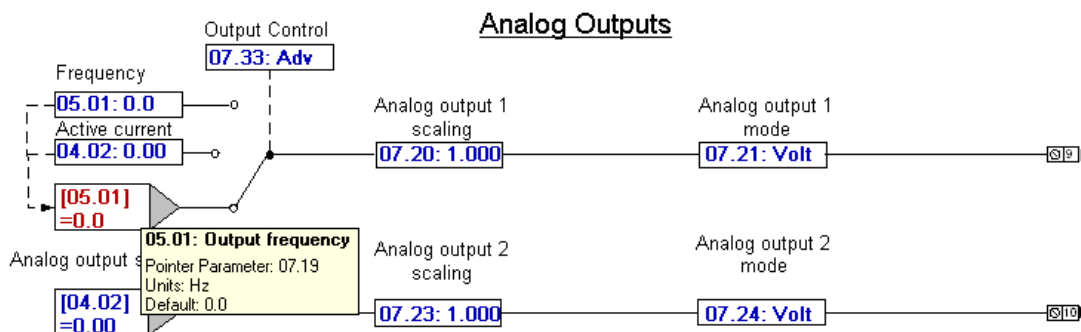
This application note is pertinent to Unidrive SP, Commander GP20 and Affinity Drives

A common application requirement calls for a drive to provide an analog output signal proportional to Motor Speed, Motor Current and occasionally Motor Power consumption. This application note will attempt to provide guidance on what one would expect to measure based on a given example.

Speed Meter

The drive has 2 Analog outputs that produce up to 10 volts. They can be assigned to virtually any internal register inside the drive range. They have scaling multipliers that provides up to 4.000 scaling factor.

As shown below, in the Open Loop mode of operation, Analog Output #1 is defaulted to output 0-10v proportional to the Output Frequency of the drive. The output will be +10v when the drive is at its Max Frequency setting (as set by #0.02 or #1.06) in a forward direction and -10v if running in reverse.



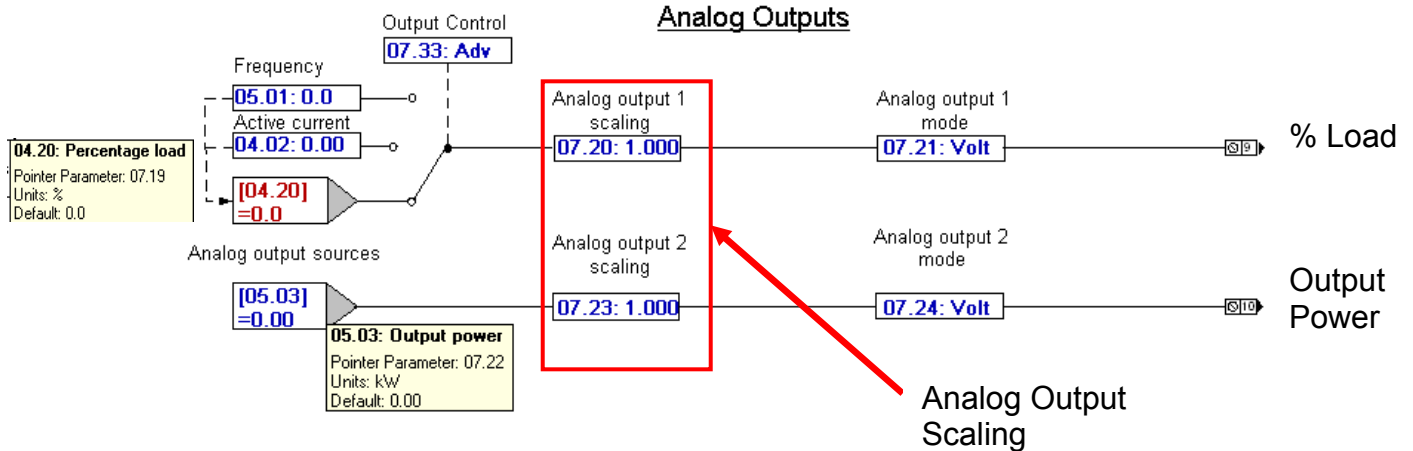
In Closed Loop modes, the Analog output would be referring to #3.02 which is the RPM of the motor. In this case, the Analog Output will be 5v at the Max RPM (as set by #0.02 or #1.06)

EXAMPLE 2

Suppose one were applying a Unidrive SP5401 to drive a 460vac motor rated at 100A using the Open Loop mode of operation whose power factor was 0.93. What would one expect on the analog outputs when Current and Power is desired ?

The drive has 2 Analog outputs that produce up to 10 volts. They can be assigned to virtually any internal register inside the drive range. They have a scaling multiplier that provides up to 4.000 scaling factor.

The example below illustrates Analog Output 1 having been assigned to % Load (#4.20) and Analog Output 2 having been assigned to Output Power (#5.03).



When one assigns the drives analog outputs to the drives Current, Power and Speed registers, the outputs are scaled to the maximum internal calculations for that model.

A resource that you would need is data from Table 11.5 in the User Guide (pg 159 of Issue 12 manual). See following page for this reference.

Looking at the table for SP5401 yields a term **kc = 124** which is used for internal scaling.

This value as you might expect is used heavily throughout the drive for current related computations and scaling. From page 157 of the Issue 12 User Guide, is a definition:

DRIVE_CURRENT_MAX [9999.99A]	Maximum drive current The maximum drive current is the current at the over current trip level and is given by: DRIVE_CURRENT_MAX = K _C / 0.45
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For our example: **DRIVE_CURRENT_MAX = 124/0.45 = 275.56 or 276 A**

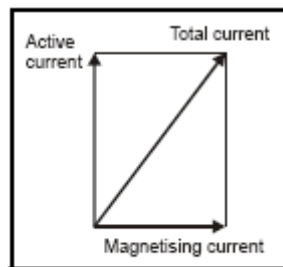
So, if one were to assign an analog output to #4.02 (the Active motor current-Torque producing component) one would expect 10v at a 276A current level. Analog output scaling is based on this level.

The extract below is from the Advanced User’s Guide Issue 8 pg 147.

Pr 4.02 - torque prod current	10.0V = K _c / 0.45 where K _c is the current scaling factor for the drive
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Or 4.5v at the kc value in this case 4.5v at 124A.

Similarly, this could be done for #4.01 which is the Total Output current (magnitude). You would read 4.5v if #4.01 was displaying 124A.



The active current is the torque producing current and the reactive current is the magnetising or flux-producing current.

The full scale rating of the Analog outputs is 10v

$$\begin{aligned} \text{Total Motor Current} &= \#4.01 \\ \text{Active Current} &= \#4.02 \end{aligned}$$

$$\begin{aligned} \text{Analog Output} &= (\#4.01 / \text{DRIVE_CURRENT_MAX}) * 10 \\ &= (\#4.01/276) * 10 \end{aligned}$$

$$\text{Or} = (\#4.02/276) * 10$$



Table 11-5 Maximum motor rated current

Model	Kc	Maximum Heavy Duty current rating (Pr 11.32) A	Maximum Normal Duty current rating A
SP0201	2.2	2.2	2.2
SP0202	3.1	3.1	3.1
SP0203	4.0	4.0	4.0
SP0204	5.7	5.7	5.7
SP0205	7.5	7.5	7.5
SP1201	4.3	4.3	6.2
SP1202	5.8	5.8	6.8
SP1203	7.5	7.5	9.6
SP1204	10.6	10.6	11
SP2201	12.8	12.8	15.5
SP2202	17.0	17.0	22.0
SP2203	25.0	25.0	28.0
SP3201	31.0	31.0	42.0
SP3202	42.0	42.0	54.0
SP4201	58.0	58.0	68.0
SP4202	68.0	68.0	80.0
SP4203	80.0	80.0	104.0
SP5201	105.0	105.0	130.0
SP5202	130.0	130.0	154.0
SP0401	1.3	1.3	1.3
SP0402	1.7	1.7	1.7
SP0403	2.1	2.1	2.1
SP0404	3.0	3.0	3.0
SP0405	4.2	4.2	4.2
SP1401	2.1	2.1	2.8
SP1402	3.0	3.0	3.8
SP1403	4.2	4.2	5.0
SP1404	5.8	5.8	6.9
SP1405	7.6	7.6	8.8
SP1406	9.5	9.5	11.0
SP2401	13.0	13.0	15.3
SP2402	16.5	16.5	21.0
SP2403	23.0	25.0	29.0
SP2404	29.0	29.0	29.0
SP3401	32.0	32.0	35.0
SP3402	40.0	40.0	43.0
SP3403	48.0	48.0	58.0
SP4401	60.0	60.0	68.0
SP4402	74.0	74.0	83.0
SP4403	98.0	98.0	104.0
SP5401	124.0	124.0	138.0
SP5402	156.0	156.0	168.0
SP6401	154.2	180.0	205.0
SP6402	180.0	210.0	238.0
SP3501	4.1	4.1	5.4
SP3502	5.4	5.4	6.1
SP3503	6.1	6.1	8.4
SP3504	9.5	9.5	11.0
SP3505	12.0	12.0	16.0
SP3506	18.0	18.0	22.0
SP3507	22.0	22.0	27.0
SP4601	19.0	19.0	22.0
SP4602	22.0	22.0	27.0
SP4603	27.0	27.0	36.0
SP4604	36.0	36.0	43.0
SP4605	43.0	43.0	52.0
SP4606	52.0	52.0	62.0
SP5601	63.0	63.0	84.0
SP5602	85.0	85.0	99.0
SP6601	85.7	100.0	125.0
SP6602	107.1	125.0	144.0



Rated Active and Magnetizing Current

Rated Active (torque producing) current is the rated or Nameplate current x the motor Power Factor which in our case is: $FLA * pf = 100A * 0.93$ or **93A**.

The magnetizing current is $\sqrt{(1-pf^2)} * FLA = \sqrt{1-0.8649} * 100 = 0.3675 * 100 = \mathbf{36.8A}$

Keeping in mind that the default peak torque current (%Motor Load) available in Open Loop mode is 165% of the Motor Rated Active Current which in our case is:

Peak Active Current = $1.65 * 93A = 153.5 A$

The Active Current is the % Load x the Rated Active Current

Total Motor Current is the measured current to the motor.

Total Motor Current = $\sqrt{I_{mag}^2 + I_{active}^2}$

Which at 100% Load = $\sqrt{36.8^2 + 93^2} = 100 A$

From the above facts, the following table could be derived.

% Load # 4.20	Total Motor Current # 4.01 A	Active Current # 4.02 A	Analogue Output when tagged to		
			# 4.01 V	# 4.02 V	# 4.20 V
0%	36.8	0.0	1.33	0.00	0.00
20%	41.2	18.6	1.49	0.68	1.21
50%	59.3	46.5	2.15	1.69	3.03
70%	74.8	65.1	2.71	2.36	4.24
100%	100.0	93.0	3.63	3.38	6.06
120%	117.5	111.6	4.26	4.05	7.27
150%	144.3	139.5	5.24	5.06	9.09
165%	157.8	153.5	5.73	5.57	10.00

It should be noted that #4.20 is scaled by #4.24. The default for #4.24 is open loop is 165%.

Authors Note

I am always skeptical when one is requested to display amps for a motor. I usually ask , **“For whom is the display intended ?”** If the answer is “the Operator”, I believe that we are doing a disservice in doing so. Motor amps are somewhat foreign and arbitrary to an Operator. One machine may be quite different from another. %Load is always relevant from one machine to another. 100% Load means the motor is at its rated capacity regardless if it is 25A or 2500A.

For this reason, I would suggest that one consider displaying #4.20 which is % Load.

Driving an Analog Ammeter

% Load # 4.20	Total Motor Current # 4.01 A	Active Current # 4.02 A	Analogue Output when tagged to		
			# 4.01 V	# 4.02 V	# 4.20 V
0%	36.8	0.0	1.33	0.00	0.00
20%	41.2	18.6	1.49	0.68	1.21
50%	59.3	46.5	2.15	1.69	3.03
70%	74.8	65.1	2.71	2.36	4.24
100%	100.0	93.0	3.63	3.38	6.06
120%	117.5	111.6	4.26	4.05	7.27
150%	144.3	139.5	5.24	5.06	9.09
165%	157.8	153.5	5.73	5.57	10.00

Per Example 2:

If one decides to display either the Total Current or the Active Current on a 10v full scale analog meter whose face was scaled from 0 to 150 and labeled with AMPS, one would scale the analog output as follows:



If #4.01 selected, the Analog Output Scaler needs to be such that at 150A the meter will read full scale. The drive can provide 165% current which will result in 157.8A and 5.73v on the analog output. So at 150A we would see $\frac{150}{157.8} = 0.95 \times 5.73v$ or 5.447v.

So to make the meter read 150, we would need a scale factor of $10/5.447 = 1.836$. Obviously the meter will peg should the current exceed 156% ($0.95 \times 165\%$) but this would not be too severe for the meter. The correct method would be use a meter face with 175A or at least 160A in this case.

If #4.02 selected, the Analog Output Scaler needs to be such that at 150A the meter will read full scale. The drive can provide 165% current which will result in 153.5A and 5.57v on the analog output. So at 150A we would see $\frac{150}{153.5} = 0.977 \times 5.57v$ or 5.443v.

So to make the meter read 150, we would need a scale factor of $10/5.443 = 1.837$. Obviously the meter will peg should the current exceed 161% ($0.977 \times 165\%$) but this would not be too severe for the meter. The correct method would be use a meter face with 175A or at least 160A in this case.

Power Output Setup

The approximate¹ Power Output as displayed by parameter #5.03 is:

$$\text{Power Output}_{\text{kW}} = \frac{\sqrt{3} \times \text{Vout} \times \text{Active Current}}{1000}$$

Where output voltage is the same as motor rated voltage assuming that the motor is running at rated frequency and hence the output volts equals motor rated volts.

The power output calculation is based on the term discussed earlier **DRIVE_CURRENT_MAX**

For our example: **DRIVE_CURRENT_MAX** = 124/0.45 = 275.56 or **276 A**

And **AC_VOLTAGE_MAX** is 650 for 400volt drives such as the SP5401
(780vac for a 575volt model and 930vac for a 690v model)

$$\text{Power}_{\text{max}} = \sqrt{3} \times \text{AC_VOLTAGE_MAX} \times \text{DRIVE_CURRENT_MAX}$$

For our example this becomes:

$$\text{Power}_{\text{max}} = \frac{1.73 \times 650 \times 276}{1000} = \mathbf{310 \text{ KW}}$$

Per our example motor, at 100% load the analog output would be :

$$\begin{aligned} \text{Power Output}_{\text{kW}} &= \frac{\sqrt{3} \times 460\text{v} \times \text{Active Current}}{1000} \\ &= \frac{1.73 \times 460\text{v} \times 93\text{A}}{1000} = \sim 74\text{kW} \end{aligned}$$

When an analog output is assigned to #5.03, the scaling is based on $\text{Power}_{\text{max}}$

$$\text{Analog Output} = \frac{\text{Power}}{\text{Power}_{\text{max}}} \times 10 = \frac{74}{310} \times 10 = 2.38\text{v}$$

To continue our table, we can include the approximate derived Power Output on the Analog Output table.

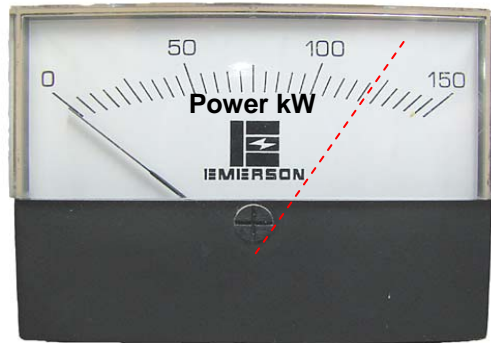
% Load	Total Motor Current	Active Current	Power (approx)	Analogue Output when tagged to			
				# 4.01	# 4.02	# 4.20	# 5.03
# 4.20	# 4.01	# 4.02	# 5.03	# 4.01	# 4.02	# 4.20	# 5.03
	A	A	kW	V	V	V	V
0%	36.8	0.0	0.0	1.33	0.00	0.00	0.00
20%	41.2	18.6	14.8	1.49	0.68	1.21	0.48
50%	59.3	46.5	37.0	2.15	1.69	3.03	1.19
70%	74.8	65.1	51.9	2.71	2.36	4.24	1.67
100%	100.0	93.0	74.1	3.63	3.38	6.06	2.39
120%	117.5	111.6	88.9	4.26	4.05	7.27	2.87
150%	144.3	139.5	111.1	5.24	5.06	9.09	3.58
165%	157.8	153.5	122.3	5.73	5.57	10.00	3.94

¹This is a practical approximation as the actual power computation is significantly more complex. The computation would involve dot product mathematics for a more exact calculation which would require far too much computation time and burden placed on the drives microcomputer vs the approximation.

Driving an Analog Power Meter

Per Example 2:

If one decides to display either the Power Output on a 10v full scale analog meter whose face was scaled from 0 to 150 and labeled with Power kW, one would scale the analog output as follows:



If #5.03 selected, the Analog Output Scaler needs to be such that at full drive output the meter will read 122kW. The drive can provide 165% current which will result in 122kW and 3.94v on the analog output. Since 10v would cause 150kW to be displayed, what voltage would be required to display 122kW? So at 122 we would see $\frac{122}{150} = 0.813 \times 10\text{v}$ or 8.13v.

So to make the meter read 122 we need 8.13v, therefore we would need a scale factor of $8.13/3.94 = 2.063$

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