

# Recommended startup of PowerFlex 525 with sPM and IPM Motors

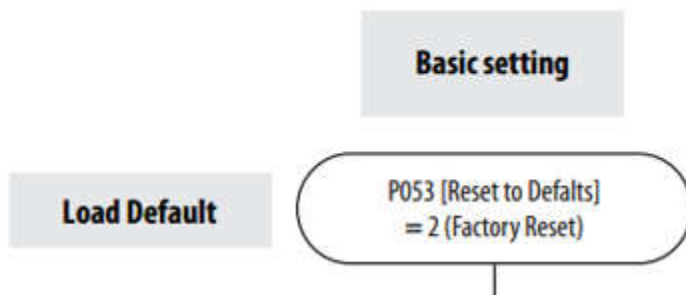
There are two types of PM motor support:

1. Open loop sPM (surface permanent magnet), sPM closed loop *is not* supported.
2. Open loop IPM (interior permanent magnet), closed loop IPM with encoder feedback.

Publication 520-UM001 has information about setup and configuration. This document is to aid and enhance the flowcharts and suggestions based on testing with several motors.

[http://literature.rockwellautomation.com/idc/groups/literature/documents/um/520-um001\\_-en-e.pdf](http://literature.rockwellautomation.com/idc/groups/literature/documents/um/520-um001_-en-e.pdf)

## Flowchart for Open Loop PM Motor (iPM and sPM) Setup



Reset the drive to load defaults if the drive has been programmed for other functions or if the drive has just been taken out of the box condition this step is not as necessary.

### P053 [Reset To Defaults]



Stop drive before changing this parameter.

Resets all parameters to their factory default values. After a Reset command, the value of this parameter returns to zero.

Options	0	"Ready/Idle" (Default)
	1	"Param Reset" Does not reset custom groups, parameter P030 [Language], and communication parameters.
	2	"Factory Rset" Restore drive to factory condition.
	3	"Power Reset" Resets only power parameters. Can be used when swapping power modules.
	4	"Module Reset" <sup>(1) (2)</sup> Power cycle of the drive, <b>NO</b> parameters are reset.

(1) Setting is available in PowerFlex 525 FRN 5.xxx and later.


(2) Setting is available in PowerFlex 523 FRN 3.xxx and later.



In version 5.xxx and later permanent magnet motor control mode was added.

**P039 [Torque Perf Mode]**

Related Parameter(s): [P040](#), [A530](#), [A531](#), [A532](#), [A533](#), [A535](#)

 Stop drive before changing this parameter.

Selects the motor control mode.

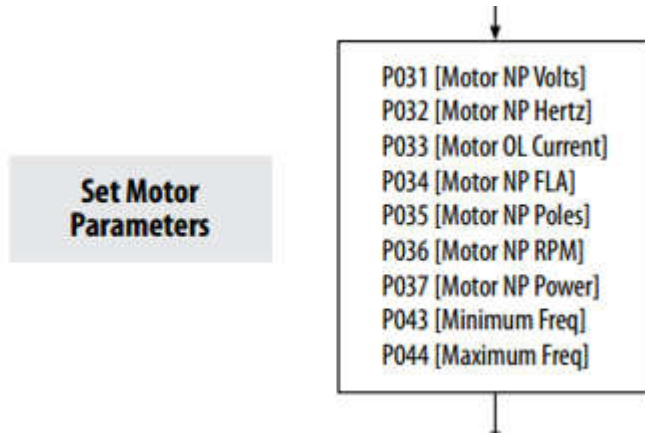
The PowerFlex 523 and PowerFlex 525 drives are capable of performing with the following motor control modes.

Options	0	"V/Hz"
	1	"SVC" (Default)
	2	"Economize"
	3	"Vector" <sup>(1)</sup>
	4	"PM Control" <sup>(1) (2)</sup>

When P039 [Torque Perf Mode] is set to 4 and [A535](#) [Motor Fdbk Type] is set to 0, 1, 2 or 3, the drive is in open loop PM motor control mode.  
 When P039 [Torque Perf Mode] is set to 4 and [A535](#) [Motor Fdbk Type] is set to 4 or 5, the drive is in closed loop PM motor control mode.

- (1) Setting is specific to PowerFlex 525 drives only.
- (2) Setting is available in PowerFlex 525 FRN 5.xxx and later.


The control mode selection of "4" is used for PM motor control. The PM algorithm is basically a Volts/Hz type algorithm with alignment, stability and efficiency gain controls to improve permanent magnet response and performance.



Motor data entry is always critical for proper operation. Here is a summary of each step as shown in the 520-UM001 Appendix I flowchart.

**P031 [Motor NP Volts]**

Related Parameter(s): [b004](#), [A530](#), [A531](#), [A532](#), [A533](#)

 Stop drive before changing this parameter.

Sets the motor nameplate rated volts.

Values	Default:	Drive Rated Volts
	Min/Max:	10V (for 230V Drives), 20V (for 460V Drives), 25V (for 600V Drives)/Drive Rated Volts
	Display:	1V

Parameter 31 is motor NP Volts, it is recommended to have a drive input voltage of 460 VAC controlling a 460 VAC motor. It is not recommended to use a 460 VAC input to a 460 VAC input drive that controls a 230 VAC motor. One reason is the motor dielectric strength may not handle that voltage. Motor Voltage is used in the motor equivalent circuit tests and calculations of autotune.

**P032 [Motor NP Hertz]**Related Parameter(s): [A493](#), [A530](#), [A531](#), [A532](#), [A533](#) Stop drive before changing this parameter.

Sets the motor nameplate rated frequency.

<b>Values</b>	Default:	60 Hz
	Min/Max:	15/500 Hz
	Display:	1 Hz

Motor frequency along with motor poles determine the synchronous speed. A normal induction motor is 60 Hz for 4 poles that would be 1800 synchronous speed minus a slip. However a PM motor does not have slip and based on speed requirements and construction, has varying frequency and pole construction. Typical high performance sPM motors are 8 pole type. A pancake type motor can have 10+ poles for more torque generation as the motor rotor cuts flux from pole to pole making smooth transitions and better low speed performance.

Use the synchronous speed =  $120 \times \text{frequency/poles}$ . For instance, having a 2000 RPM motor with 167 Hz and 10 poles.

**P033 [Motor OL Current]**Related Parameter(s): [t069](#), [t072](#), [t076](#), [t081](#), [A484](#), [A485](#), [A493](#)

Sets the motor nameplate overload current. Used to determine motor overload conditions and can be set from 0.1 A to 200% of drive rated current.

**IMPORTANT** The drive will fault on an F007 "Motor Overload" if the value of this parameter is exceeded based on class 10 motor overload protection according to NEC article 430 and motor over-temperature protection according to NEC article 430.126 (A) (2). UL 508C File 29572

<b>Values</b>	Default:	Drive Rated Amps
	Min/Max:	0.0/(Drive Rated Amps x 2)
	Display:	0.1 A

Set per motor manufacturer data sheet

**P034 [Motor NP FLA]**Related Parameter(s): [P040](#)

Sets the motor nameplate FLA. Used to assist the Autotune routine and motor control.

<b>Values</b>	Default:	Based on Drive Rating
	Min/Max:	0.1/(Drive Rated Amps x 2)
	Display:	0.1 A


Motor FLA is based on motor nameplate setting.

**P035 [Motor NP Poles]**Related Parameter(s): [b015](#)

Sets the number of poles in the motor.

<b>Values</b>	Default:	4
	Min/Max:	2/40
	Display:	1

PM motors are typically 6 to 10+ pole motors.

**P036 [Motor NP RPM]** Stop drive before changing this parameter.

Sets the rated nameplate rpm of the motor. Used to calculate the rated slip of the motor. To reduce the slip frequency, set this parameter closer to the motor synchronous speed.

<b>Values</b>	Default:	1750 rpm
	Min/Max:	0/24000 rpm
	Display:	1 rpm

Remember this is synchronous speed because there is no slip in a PM motor.

This parameter works alongside Parameter 35 Motor NP Poles and parameter 32 Motor NP Hertz for the proper synchronous speed.

---

**P037 [Motor NP Power]**

(PF 525) PowerFlex 525 only.

Sets the motor nameplate power. Used in PM regulator.

<b>Values</b>	Default:	Drive Rated Power
	Min/Max:	0.00/Drive Rated Power
	Display:	0.01 kW

---

Motor nameplate power in kW. **Note:** This is must be correct as it is used in tuning calculations.

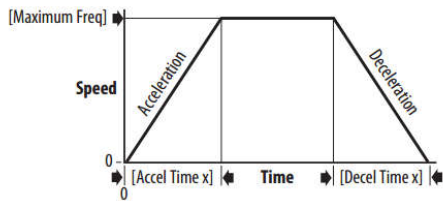
---

**P041 [Accel Time 1]**

Related Parameter(s): [P044](#), [A439](#)

Sets the time for the drive to accelerate from 0 Hz to [P044](#) [Maximum Freq].

Accel Rate = [Maximum Freq] / [Accel Time x]



<b>Values</b>	Default:	10.00 s
	Min/Max:	0.00/600.00 s
	Display:	0.01 s

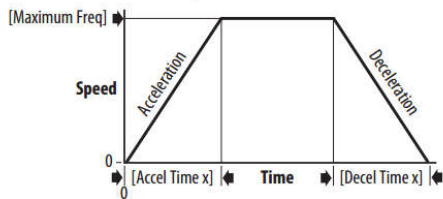
---

**P042 [Decel Time 1]**

Related Parameter(s): [P044](#), [A439](#)

Sets the time for the drive to decelerate from [P044](#) [Maximum Freq] to 0 Hz.

Decel Rate = [Maximum Freq] / Decel Time x]




<b>Values</b>	Default:	10.00 s
	Min/Max:	0.00/600.00 s
	Display:	0.01 s

---

Parameters 41 and 42 are the acceleration and deceleration times that the drive controls the motor from 0 to P44 maximum frequency and from maximum frequency to 0.

**P043 [Minimum Freq]**

Related Parameter(s): [b001](#), [b002](#), [b013](#), [P044](#), [A530](#), [A531](#)

 Stop drive before changing this parameter.

Sets the lowest frequency the drive outputs.


<b>Values</b>	Default:	0.00 Hz
	Min/Max:	0.00/500.00 Hz
	Display:	0.01 Hz

---

Minimum frequency is the minimum frequency the drive will ramp to upon a start command if set greater than zero.

**P044 [Maximum Freq]**

Related Parameter(s): [b001](#), [b002](#), [b013](#), [b016](#), [P043](#), [A530](#), [A531](#)

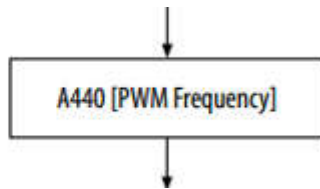
 Stop drive before changing this parameter.

Sets the highest frequency the drive outputs.

**IMPORTANT** This value must be greater than the value set in P043 [Minimum Freq].

<b>Values</b>	Default:	60.00 Hz
	Min/Max:	0.00/500.00 Hz
	Display:	0.01 Hz

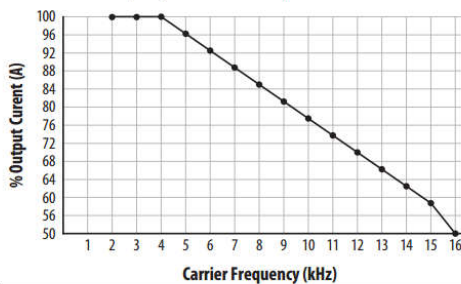
Maximum frequency is defaulted to 60 Hz. For most PM motors this has to be changed. Improper current draw and speed regulation will occur if this is not set to the proper motor requirement. During rotate autotune, as shown later in this document, requires the motor run up to the frequency in parameter 32. If P44 is not set above that the autotune will fail.



**A440 [PWM Frequency]**

Related Parameter(s): [A540](#)

Sets the carrier frequency for the PWM output waveform. The chart below provides derating guidelines based on the PWM frequency setting.



Note: If Vector mode (open loop) is selected and 16 kHz is selected, the drive will forcibly reduce the carrier frequency to 8 kHz.

**IMPORTANT** Ignoring derating guidelines can cause reduced drive performance. The drive may automatically reduce the PWM carrier frequency at low output speeds, unless prevented from doing so by A540 [Var PWM Disable].

<b>Values</b>	Default:	4.0 kHz
	Min/Max:	2.0/16.0 kHz
	Display:	0.1 kHz

Motor manufacturers have recommended drive PWM frequency settings. The lower the PWM frequency the lower the stress on the power module. The higher the PWM the higher stress on the drive IGBT based on load current requirements. Typically left at default value.

## Set PG

A535 [Motor Fdbk Type]  
= 0 (None)

### A535 [Motor Fdbk Type]

Related Parameter(s): [P039](#), [A537](#)

 Stop drive before changing this parameter.

Selects the encoder type.<sup>(1)</sup>



**ATTENTION:** The loss of analog input, encoder or other feedback may cause unintended speed or motion. Take appropriate precautions to guard against possible unintended speed or motion.

	Allowable Control Modes (See <a href="#">P039</a> [Torque Perf Mode])	Hardware Inputs
<b>Options</b>		
0 "None" (Default)	V/Hz, SVC, Economize, Vector, PM Control	–
1 "Pulse Train"	V/Hz, SVC, Economize, PM Control	[DigIn TermBlk 05] for PowerFlex 523 [DigIn TermBlk 07] for PowerFlex 525
2 "Single Chan" <sup>(2)</sup>	V/Hz, SVC, Economize, PM Control	
3 "Single Check" <sup>(2)</sup>	V/Hz, SVC, Economize, PM Control	Optional incremental encoder card (catalog number 25-ENC-1)
4 "Quadrature" <sup>(2)</sup>	V/Hz, SVC, Economize, Vector, PM Control	
5 "Quad Check" <sup>(2)</sup>	V/Hz, SVC, Economize, Vector, PM Control	

Parameter 535 is default to 0 or NONE which should be used for open loop control

## A516 [PM Initial Sel]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

PM initial angle detect.

<b>Options</b>	0 "Align" (Default)	
	1 "HFI"	High Frequency Injection to detect initial angle.
	2 "Six Pulse"	

A516 is the selection of commutation angle detection to be used. Start with the default value.

---

### A517 [PM DC Inject Cur]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Maximum DC current in amps applied to the motor in order to reset the rotor position of a PM motor.

<b>Values</b>	Default:	30%
	Min/Max:	0/300%
	Display:	1%

---

### A518 [PM Align Time]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Magnetic pole reorientation time.

<b>Values</b>	Default:	0.7 s
	Min/Max:	0.0/60.0 s
	Display:	0.1 s

---

Align and Six Step are a voltage injection into the stator winding to detect the rotor magnet alignment. A517 and A518 are associated with these test methods

---

### A519 [PM HFI NS Cur]

**PF 525** PowerFlex 525 only.


(With FRN 5.xxx and later.)

High Frequency Injection (HFI) North South Current to detect N/S Magnet.

<b>Values</b>	Default:	100%
	Min/Max:	0/300%
	Display:	1%

---

A516 set to HFI would require the use of A519 for the current rating of HF injection, which is a detection of the motor rotor magnet by injecting a frequency amplitude in percentage.

**P040 [Autotune]**Related Parameter(s): [P034](#), [P039](#), [A496](#), [A497](#) Stop drive before changing this parameter.

Enables a static (not spinning) or dynamic (motor spinning) autotune to automatically set the motor parameters. Set the parameter value to a one or two, then issue a valid "Start" command to begin the routine. After the routine is complete the parameter resets to a zero. A failure (such as if a motor is not connected) results in an Autotune Fault.

It is recommended to perform a full rotate tune when using VVC mode.

---

**IMPORTANT** All motor parameters in the Basic Program group must be set before running the routine. If a start command is not given (or a stop command is given) within 30 s, the parameter automatically returns to a zero and an Autotune Fault occurs.

---

**ATTENTION:** Rotation of the motor in an undesired direction can occur during this procedure. To guard against possible injury and/or equipment damage, it is recommended that the motor be disconnected from the load before proceeding.

---

<b>Options</b>	0	"Ready/Idle" (Default)	
	1	"Static Tune"	A temporary command that initiates a non-rotational motor stator resistance test for the best possible automatic setting of <a href="#">A496</a> [IR Voltage Drop]. A start command is required following initiation of this setting. The parameter returns to 0 "Ready/Idle" following the test, at which time another start transition is required to operate the drive in normal mode. Used when motor cannot be uncoupled from the load.
	2	"Rotate Tune"	A temporary command that initiates a "Static Tune" followed by a rotational test for the best possible automatic setting of <a href="#">A497</a> [Flux Current Ref]. A start command is required following initiation of this setting. The parameter returns to 0 "Ready/Idle" following the test, at which time another start transition is required to operate the drive in normal mode. Important: Used when motor is uncoupled from the load. Results may not be valid if a load is coupled to the motor during this procedure.

---

Set P040 autotune for rotate tune. The motor must be unloaded then start the drive to run the autotune procedure. Autotune will measure and populate parameter 501 -504.

---

**A501 [PM IR Voltage]** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Voltage across the stator resistance of the PM motor at the rated motor current displayed in line-to-line rms value.

---

<b>Values</b>	Default:	11.50V
	Min/Max:	0.00/655.35V
	Display:	0.01V

---

**A502 [PM IXd Voltage]** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Voltage across the d-axis stator inductance of the PM motor at the rated motor current and the rated motor frequency displayed in line-to-line rms value.

---

<b>Values</b>	Default:	17.91V
	Min/Max:	0.00/655.35V
	Display:	0.01V

---

**A503 [PM IXq Voltage]** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Voltage across the q-axis stator inductance of the PM motor at the rated motor current and the rated motor frequency displayed in line-to-line rms value.

---

<b>Values</b>	Default:	53.21V
	Min/Max:	0.00/655.35V
	Display:	0.01V

---

For a SPM motor there is no reluctance torque so A502 should be approximate the same as A503.

For an IPM motor there is reluctance torque so A502 and A503 should be different.



The final part of the autotune is a counter EMF test that spins the motor to maximum motor frequency as shown in parameter 32. Note, remember that P44 must be set to this value for the autotune to properly complete.

---

**A504 [PM BEMF Voltage]**

PF 525 PowerFlex 525 only.

(With FRN 5.xxx and later.)

Back electromotive force (EMF) voltage.

---

<b>Values</b>	Default:	1640.0 Drive Rated Volts
	Min/Max:	0.0/6000.0 Drive Rated Volts
	Display:	0.1V

---

After performing an autotune on an open loop PM motor, a momentary “reverse startup” may occur. To prevent this from occurring, perform the following steps:

1. Set A516 [PM Initial Sel] = 1 “HFI”.
2. Increase the value of A519 [PM HFI NS Cur] by 10%.
3. Perform a test run at a reference speed and check if the motor reverses.
4. If the motor reverses, repeat steps 2 and 3.
5. If A519 [PM HFI NS Cur] has reached its maximum value (200%):
  - reset the value to the default (100%)
  - set A516 [PM Initial Sel] = 2 “Six Pulse”
6. Perform a test run at a reference speed and check if the motor reverses.
7. If the motor reverses, repeat steps 2 and 3.
8. If A519 [PM HFI NS Cur] has reached its maximum value again and a reverse motor startup still occurs, the motor setup has failed.

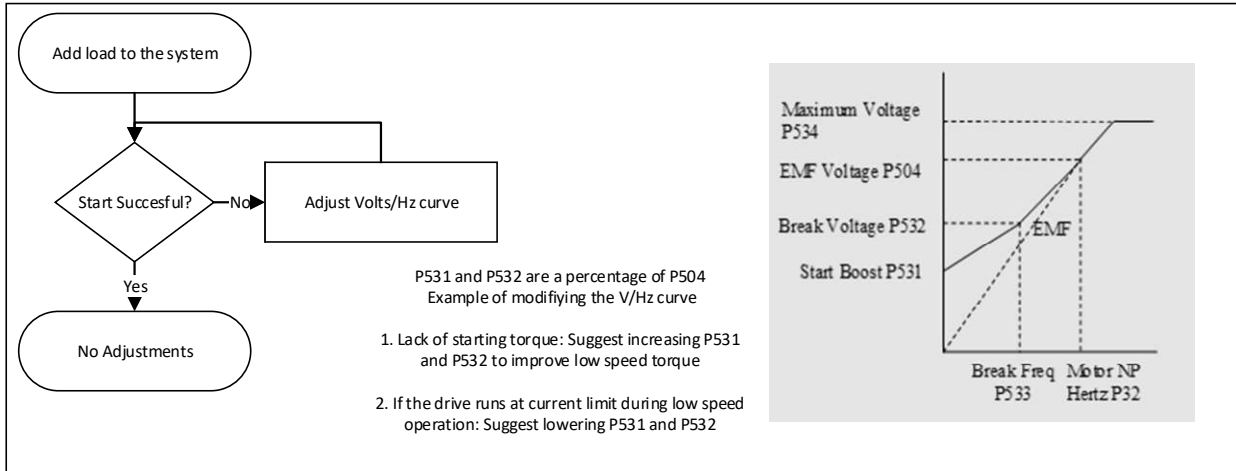
Giving a start command and speed reference should generate good PM performance.

**Setup should be complete. See Appendix A of this document for a flow charted sequence of steps. If additional tuning is required continue to the Additional Tuning Options.**

## Additional Tuning options

### Starting Loaded V/Hz Tuning

If after loading the motor the startup is not successful, adjustment of the V/Hz curve may be required. The sequence below is used for adjusting the V/Hz curve.



#### A504 [PM BEMF Voltage]

[PF 525] PowerFlex 525 only.

(With FRN 5.xxx and later.)

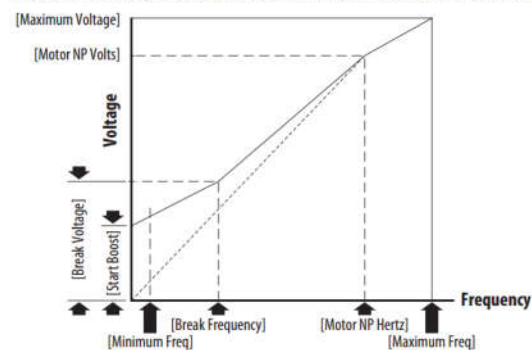
Back electromotive force (EMF) voltage.

<b>Values</b>	Default:	1640.0 Drive Rated Volts
	Min/Max:	0.0/6000.0 Drive Rated Volts
	Display:	0.1V

#### A531 [Start Boost]

Related Parameter(s): [P031](#), [P032](#), [P039](#), [A530](#)

Sets the boost voltage (% of [P031](#) [Motor NP Volts]) and redefines the V/Hz curve when [A530](#) [Boost Select] = 0 "Custom V/Hz" and [P039](#) [Torque Perf Mode] = 0 "V/Hz".



<b>Values</b>	Default:	2.5%
	Min/Max:	0.0/25.0%
	Display:	0.1%

#### A532 [Break Voltage]

Related Parameter(s): [P031](#), [P032](#), [P039](#), [A530](#), [A533](#)

Sets the voltage (in percent of [Base Frequency]) at the [A533](#) [Break Frequency] if [A530](#) [Boost Select] is set to 0 "Custom V/Hz".

<b>Values</b>	Default:	25.0%
	Min/Max:	0.0/100.0%
	Display:	0.1%

**A533 [Break Frequency]**Related Parameter(s): [P031](#), [P032](#), [P039](#), [A530](#), [A532](#)

Sets the frequency where [A532](#) [Break Voltage] is applied if [A530](#) [Boost Select] is set to 0 "Custom V/Hz".

---

<b>Values</b>	Default:	15.0 Hz
	Min/Max:	0.0/500.0 Hz
	Display:	0.1 Hz

---

## DC Bus Overvoltage Faults

---

### A520 [PM Bus Reg Kd]

PF 525 PowerFlex 525 only.

(With FRN 5.xxx and later.)

Derivative gain for bus regulator.

<b>Values</b>	Default:	2
	Min/Max:	0/500
	Display:	1

---

A520 Parameter PM Bus Regulator Kd, If rapid changes in load or rapid deceleration rates cause a DC Bus Overvoltage fault then increase this parameter.

## Closed Loop Velocity Stabilization

---

### A527 [PM FWKn 1 Kp]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

The gain to ensure good performance in field weakening region.

<b>Values</b>	Default:	250%
	Min/Max:	0/2000%
	Display:	1%

---

### A528 [PM FWKn 2 Kp]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

The gain to ensure robustness under step load in weakening region.

<b>Values</b>	Default:	100%
	Min/Max:	100/8000%
	Display:	1%

---

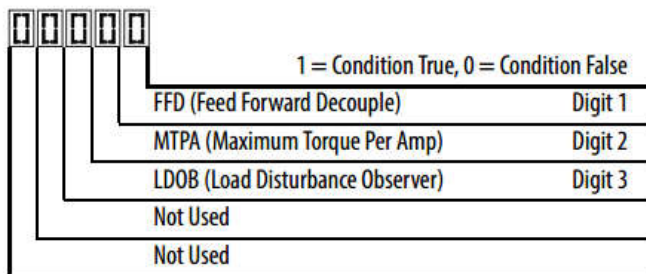
A527 and A528 are used only for an IPM motor closed loop control when going above base speed, both for performance in the above base speed to maximum speed range.

### A529 [PM Control Cfg]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Control configuration for Feed Forward Decouple (FFD), Maximum Torque Per Amp (MTPA), and Load Disturbance Observer (LDOB).



<b>Values</b>	Default:	00111
	Min/Max:	00000/00111
	Display:	00000

---

---

## A580 [Current Loop BW]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Current loop bandwidth (0 = Automatically calculate the control gain of current loop).

---

<b>Values</b>	Default:	0 Hz
	Min/Max:	0/65535 Hz
	Display:	1 Hz

---

A580 is only used in Closed Loop IPM control. Decrease A580 in increments of 50 if there is instability in the system. Increase A580 in increments of 50 to increase the response to load or speed changes.

## Stabilization Loop

P581 [PM Stable 1 Freq] the start frequency for stabilization loop (P032 [Motor NP Hertz] x A581 [PM Stable 1 Freq])

P582 [PM Stable 2 Freq] stabilization function will return to normal output after this frequency (P032 [Motor NP Hertz] x A582 [PM Stable 2 Freq])

P583 [PM Stable 1 Kp] percentage of the gain for stabilization loop. The gain is set in A584 [PM Stable 2 Kp]

P584 [PM Stable 2 Kp] the gain for stabilization loop

P585 [PM Stable Brk Pt] percentage of rated power P037 [Motor NP Power] for the gain of (A584 [PM Stable 2 Kp] x A583 [PM Stable 1 Kp])

Some motors do not operate well with the default stabilization loop curve.

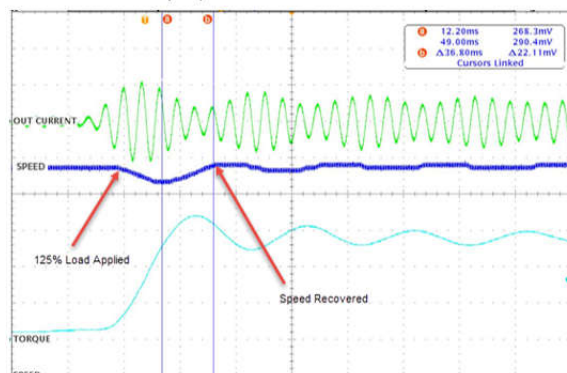
If F64 Drive overload faults occur or the motor oscillates during or after acceleration or deceleration, increase P584.

To increase the loop response decrease P584, it is possible to cause oscillations in speed if P584 is set too low.

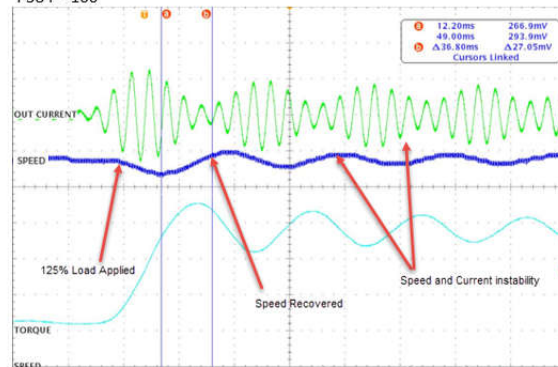
Increase or decrease P584 in increments of 100%

In the graphs below you can observe the speed recovery response time after a 125% load step load change. The faster the recovery the more likely to have speed oscillations. The times shown on the graphs are from the lowest speed after the load change until the motor recovers to commanded speed.

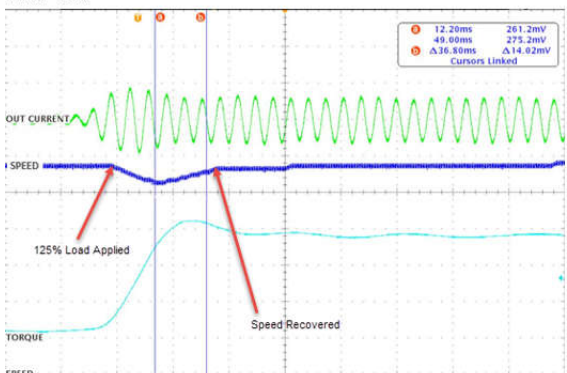
P584 = Default Value (250)



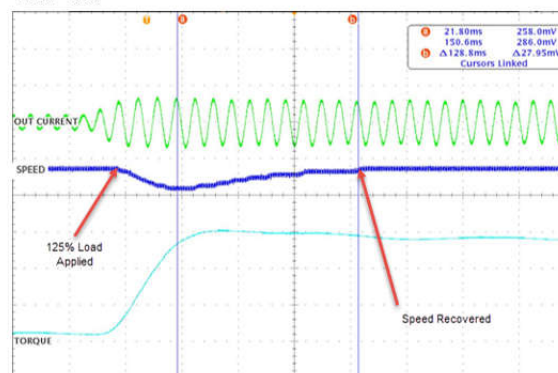
P584 = 100



P584 = 500



P584 = 970



---

## A586 [PM Stepload Kp]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

The gain to ensure robustness under step load in low speed region.

<b>Values</b>	Default:	0%
	Min/Max:	0/1000%
	Display:	1%

---

---

## A587 [PM 1 Efficiency]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Reduce full load current.

<b>Values</b>	Default:	120%
	Min/Max:	0/2000%
	Display:	1%

---

## A588 [PM 2 Efficiency]

**PF 525** PowerFlex 525 only.

(With FRN 5.xxx and later.)

Reduce no load current.

<b>Values</b>	Default:	500%
	Min/Max:	0/2000%
	Display:	1%

---



## Efficiency Compensation

P587 and P588 are Kp gains of the efficiency control

Increasing P587 can improve the efficiency of a motor at higher loading.

Increasing P587 too much will reduce the load capability of the drive motor combination.

Decreasing P587 will increase current drawn by the motor and reduce overall efficiency.

Increasing P588 will reduce the current drawn at light loading.


Increasing P588 too high can cause motor stability issues.

Decreasing P588 too much can cause the motor to draw excessive current at light loading.

---

### A589 [PM Algor Sel]

Related Parameter(s): [A550](#)

 Stop drive before changing this parameter.

[PF 525] PowerFlex 525 only.

(With FRN 5.xxx and later.)

Selects the algorithm to use with your motor. Check with the manufacturer of your motor to determine whether it is an iPM or sPM motor.

---

<b>Options</b>	0	"Algorithm 1" (Default)	Suggested for most motors.
	1	"Algorithm 2"	Enable an embedded algorithm to reduce oscillation in output waveform (use with sPM motor only, do not enable for iPM motor).

---

# Appendix A: Motor Tuning Flow

## Open Loop PM motor Startup Procedure

