Standard Drives A & D SD Application Note

SENSORLESS VECTOR CONTROL (SVC)	Version A, 30.07.99

More detail of Vector Control principles are explained in DA64 Section 2.
Some examples of SVC are given in Sections 4.2, 4.3 and 4.4.
The MICROMASTER Vector Operating Instructions describe briefly the setting of parameters for SVC operation.

DA64 Ref.	E20002-K4064-A101-A2-7600 (English)
Micro and MidiMaster Vector Operating Instructions	6SE3286-4AB66 (English)

These documents are available from Siemens sales offices or from http://www.con.siemens.co.uk

Sensorless Vector Control Operation

An inverter controls the speed of an AC motor by varying the applied frequency. The speed of the motor depends mainly on the applied frequency, but to some extent on the load as well. It is also necessary to control the voltage applied to the motor in order to maintain the correct flux in the motor.

For optimum motor performance, the exact value of flux should be controlled with respect to the rotor position as well as the load current. This requires that the stator current be controlled in magnitude and phase – the Vector quantity.

To control the phase with reference to the rotor it is necessary to know the position of the rotor. Hence for full Vector control an encoder must be used as a transducer to tell the inverter the rotor position. However many applications do not need and cannot justify the additional expense of a position encoder. In SVC, the inverter itself simulates the attributes of the encoder by means of a software algorithm which accurately calculates the rotor position and speed by mathematically modelling the properties of the motor.
To do this the inverter must:

- monitor the output and current very accurately
- calculate or measure motor parameters (rotor, stator resistance leakage inductance etc.)
- accurately model the motor thermal characteristics
- adapt motor parameters with varying motor operating conditions
- have the ability to perform these mathematical calculations very rapidly

When to use SVC

It is used to provide

- Good speed control with inherent slip compensation
- High torque at low speed without excessive boost
- Higher dynamic performance - better response to step loads
- Stable operation with large motors. Large lightly loaded motors can sometimes be unstable during inverter operation
- Better performance at current limit with improved slip control

It cannot be used for

- Synchronous or reluctance motors
- Multi-motor drives, group drives (several motors connected in parallel at the drive converter output
- Motors with power ratings less than half of the inverter rating
- Motors with power ratings greater than the inverter.

(For the above cases a V/f characteristic must be parameterised)

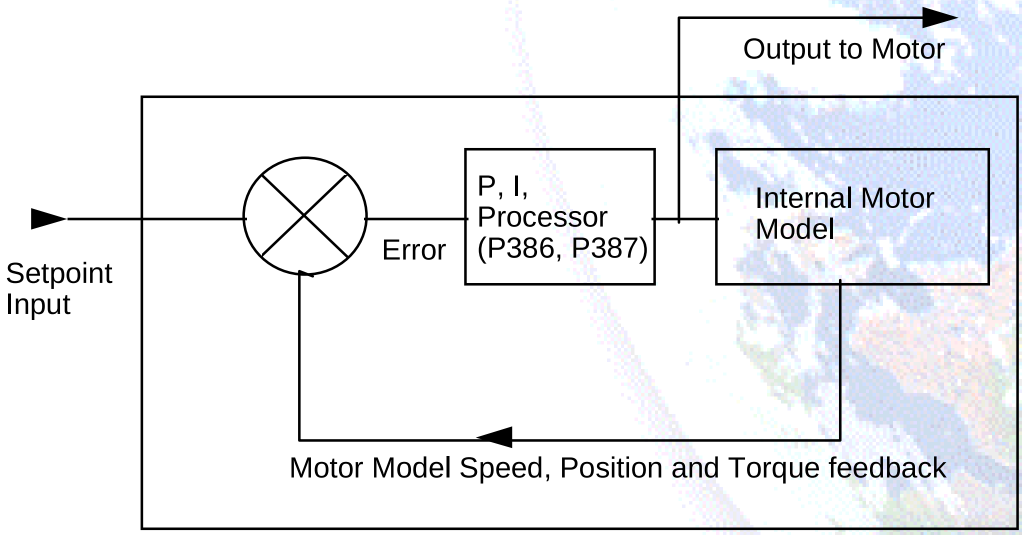
Notes on using SVC

The motor speed is controlled in this mode and this is shown in the display. That is, the frequency shown in the display is the calculated rotor frequency, not the inverter output frequency, which will usually be higher than the rotor speed due to the motor slip. In other modes output frequency is shown.
If the inverter is unable to correctly calculate the rotor position SVC is lost and a fault will be indicated.

Setting up Sensorless Vector Operation is described in the operating manual in section 5.3.3. This description is included below for completeness

5.3.3 Sensorless Vector Control (SVC) Operation (P077 = 3).

When SVC operating mode is selected (P077=3), the inverter uses an internal mathematical model of the motor, together with accurate current sensing, to calculate the position and speed of the rotor. It is therefore able to optimise the applied voltage and frequency to the motor to give improved performance.



Although there is no position or speed feedback from the motor, the control system is a closed loop system because it compares the internal motor model performance with the desired performance. The system must therefore be carefully set up and stabilised for best performance.

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Setting up SVC Operation

1. Set the correct Motor parameter settings in Parameters P080 to P085.
2. Select Sensorless Vector Operating mode P077 = 3
3. Ensure that the motor is cold and apply a run command. The display will show CAL to indicate that it is measuring the motor stator resistance. After a few seconds the motor will run. Calibration only occurs the first time that a run command is given following P077 being set to 3. It can be forced by changing P077 from SVC operation and back again, or by selecting P088 =1 (Stator Resistance Calibration. Interrupting the calibration process by disconnecting the power or removing the run command may give erroneous results and calibration should be repeated. If motor parameters are changed recalibration is also recommended.
4. ***Like any control system, SVC must be stabilised by setting the gain (P386) and Integral (P387) terms. Actual values and setting up is determined by testing, but the following procedure is suggested:***

Whilst the inverter is operating under typical conditions, increase the value of P386, the loop gain, until the first signs of speed instability occur. The setting should then be reduced slightly (approx. 10%) until stability is restored. As a guide, the optimum setting required will be proportional to the load inertia.

For example: $P386 = \dfrac{\text{Load inertia + motor shaft inertia}}{\text{motor shaft inertia}}$

P387, the integral term, may now be adjusted. Again, whilst operating the inverter under typical conditions, increment this parameter until the first signs of speed instability occur. The setting should then be reduced slightly (approx. 30%) until stability is restored.

If fault code F016 occurs, this indicates that SVC is unstable and further adjustment or recalibration is needed. F001, DC link overvoltage can also be caused by instability in SVC operating mode.

Adjustment of P386 and P387. Additional Notes.

P386 Sensorless vector speed control loop gain -proportional term

The default setting is 1.0. The range is 0.0 to 20.0. To optimise the dynamic performance of the vector control this parameter should be incremented whilst the inverter is operating under typical conditions until the first signs of instability occur. The setting should then be reduced slightly (approx. 10%). The optimum setting of P386 will be proportional to the load inertia i.e. low values of P386 correspond to low inertia loads and high values of P386 correspond to high inertia loads. If this setting is too high or too low, rapid load changes may result in DC link over voltage trips (F001) or loss of orientation (F016). The effects of different values of P386 are shown on the next page.

Note, If practical a speed feedback indicator should be used with a scope and the setting adjusted using the oscillograms illustrated on the next page. As a guide, the theoretical value of P386 is given by

P386 = (Load Inertia + motor shaft inertia)/ motor shaft inertia

P387 Sensorless vector speed control loop gain integral term

P386 must be optimised before adjusting P387. Whilst operating the inverter under typical conditions, increment this parameter until the first signs of instability occur. The setting should then be reduced slightly (approx 30%) until stability is restored. The effects of different values of P387 are shown on the next page.

Note if practical, a speed feedback indicator and scope should be used as for P386.and the setting adjusted using the oscillograms illustrated on the next page.

<u>Effects of P386 and P387</u>

100% Torque Step — Speed (rpm)

P386 Optimised (P387 = Default) — Speed (rpm)

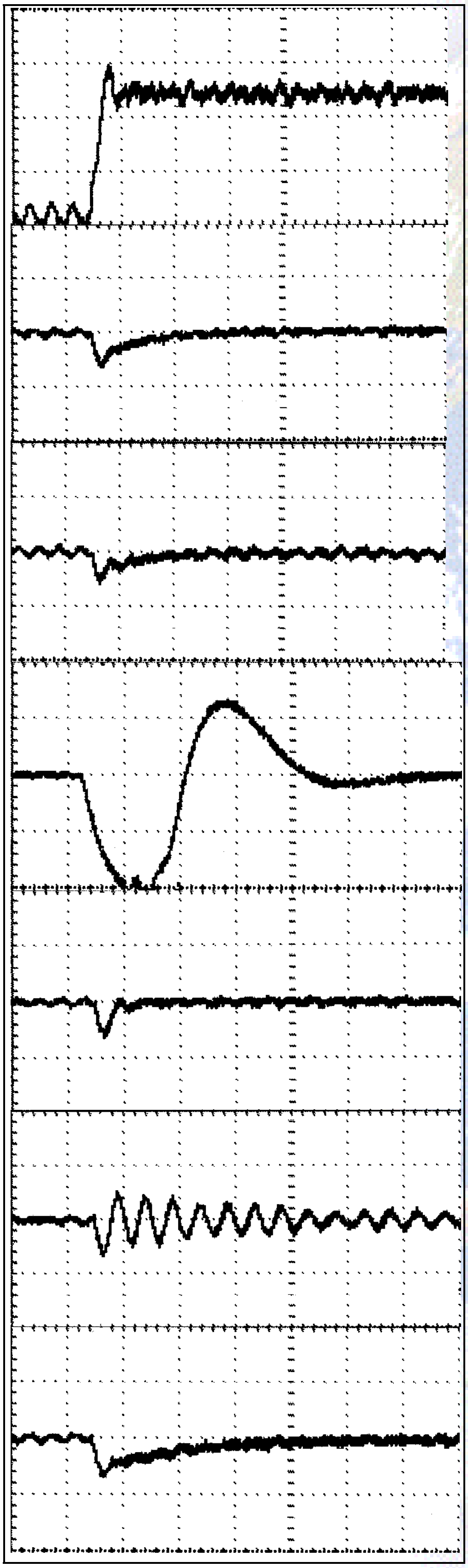
P386Too High (P387 = Default) — Speed (rpm)

P386 Too Low (P387 = Default) — Speed (rpm)

P386 Optimised P387 Optimised — Speed (rpm)

P386 Optimised P387 Too high — Speed (rpm)

P356 Optimised P387 Low Value — Speed (rpm)



Time

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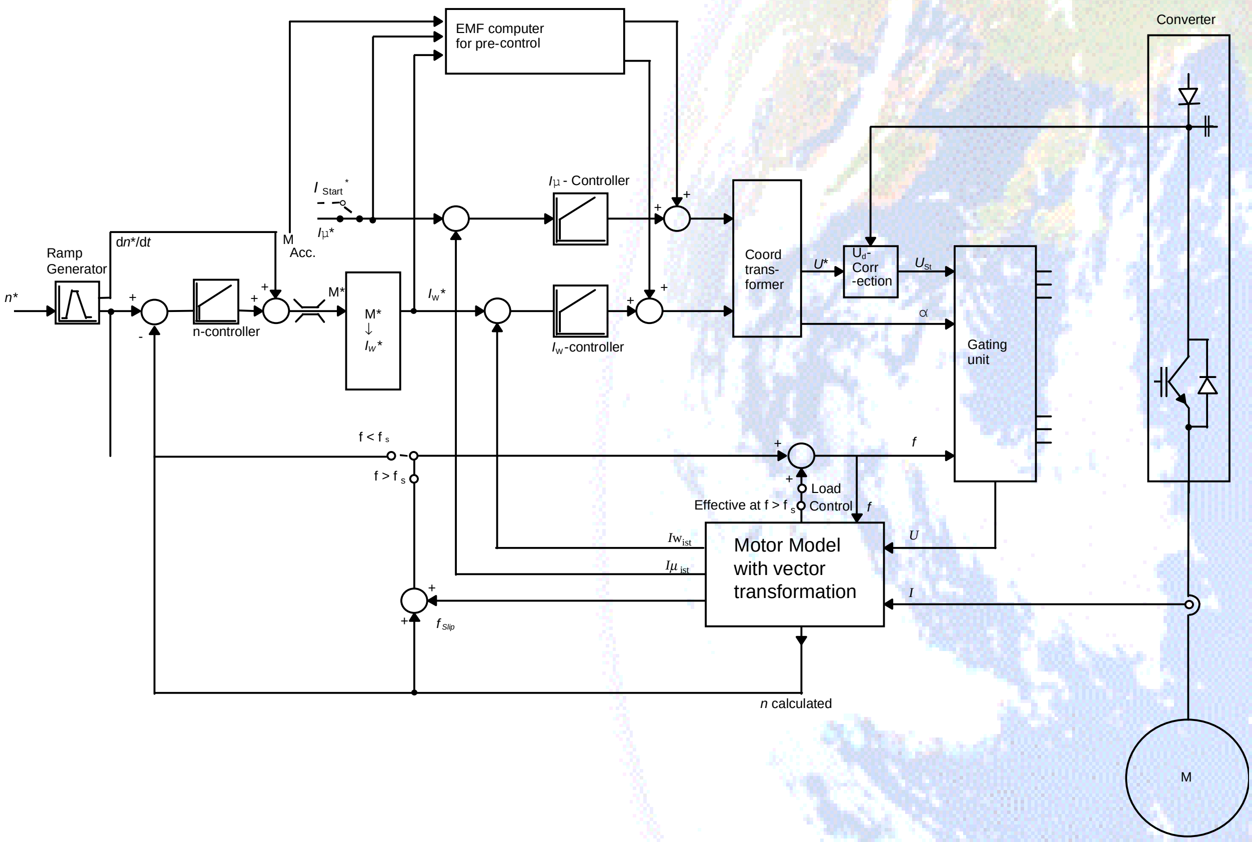
System instability will cause high motor currents, regeneration as motor speed changes rapidly, or loss of sensorless vector control. These will result in fault codes F001, F002 or F016 respectively.

Sensorless Vector control does not operate below 2.5Hz (5Hz with 2.5Hz hysterisis). In this range the inverter controls the motor torque by maintaining a constant current in the motor.

The block diagram of the Sensorless Vector control algorithm is shown below in more detail.



The control system is highly complex, and utilises software and control algorithms developed for other, larger Siemens drives together with an extremely fast floating point calculator.