SIEMENS

Whitepaper

Automotive engine test stand overview

Adding value using SINAMICS drives

usa.siemens.com/teststands

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Automotive engine test stand definition

Automotive test stands are used to test and verify powertrain product, such as engines, transmissions, differentials and more. There are many types of testing procedures — for example, in-process testing, durability testing and end-of-line test (EOLT). NVH testing is a popular test where noise, vibration and harshness is measured in the driveline.

During this testing process, the ability to control speed, torque and power on both the input and output side of the part being tested is very critical. Machines vary — from fairly simple to very complex. Having a drive family that can handle the complete range of control and power is required.

Typical automotive test stand applications

Engine testing — cold test (in-process) or hot test (EOLT)

Cold test

- Drive requirements range from 10–200 hp (typical)
- Tight control of speed regulation required, in many cases torque calculations
- From the drive, torque estimation is used in the test

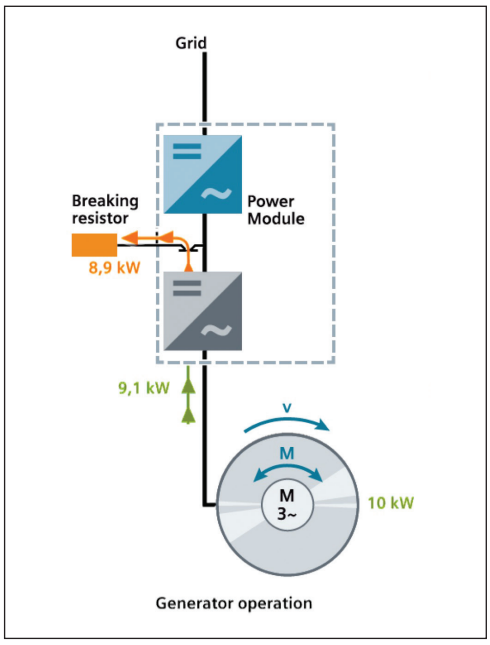
Hot test

- Drive requirements range from 100–2500+ hp (typical)
- Tight control of speed regulation required, braking (absorbing) and bumpless switchover from speed to torque mode as the engine may start in the process control of the test stand
- Full regenerative drive is preferred to save energy

Specific drive power arrangements for test stands

Full regenerative front-end arrangment

In a single-axis arrangement, where the AC motor is acting as a load, energy will bleed across a large brake resistor or more commonly a full regenerative line module. The line module is sized for line power and braking power. Typical applications include engine testing.



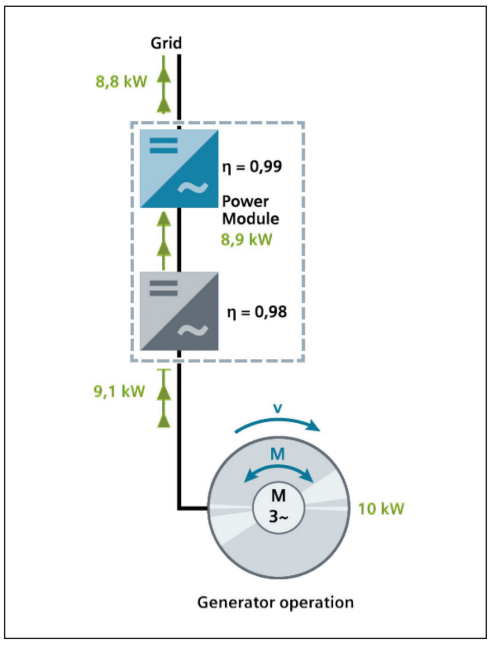


Figure 1 left:
Non-regenerative drive option
Typically used for engine cold testing, regenerative energy is dissipated in the form of heat into a brake resistor.

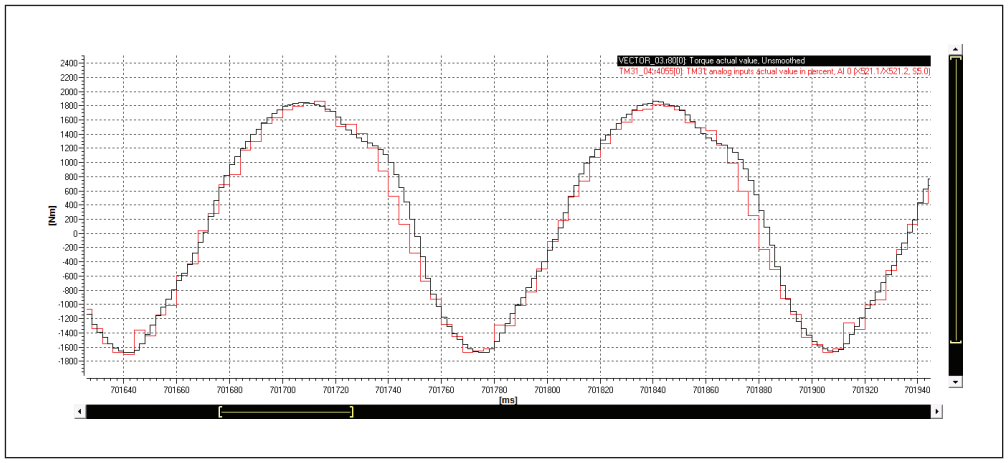
Figure 2 right:
Regenerative drive option
Typically used for engine hot testing, regenerative energy is converted back to usable line voltage and current to the mains.

Specific drive control requirements for test stands

Regulate speed and torque

In all test stand applications, tight speed or torque control is required — it is application dependent. Typical requirements are to control speed within .1% of command velocity and 2% of torque command. Siemens offers a large drive power range to cover this requirement.

Figure 3
Typical speed-torque test profile



- Existing engine cold test stand runs with constant speed setpoint
- The engine cause a periodical torque disturbance
- The control of the SINAMICS S120 make sure that the speed deviation is maximum 1% of the setpoint
- The drive calculated torque agrees very good with the external torque transducer (look at both curves)
- A saving of torque transducers for the application

Siemens offers a wide range of motors to be matched with its drives. The SIMOTICS M-1PH8 main spindle motor is a price-optimized, high performance motor in asynchronous and synchronous variants. These motors are perfect for the test stand market offering users full torque down to zero speed with high maximum speeds, as well.

This wide speed range is very conducive to the test stand market since manufacturers want to be able to use the same test stand for many different products. They are also considered servo-type motors and can provide the high torque response requirements of many test stands. Many encoder options are available for tight speed regulation.

SIMOTICS M-1PH8 main spindle motor

In most cases, the 1PH8 motor meets the speed / torque demands for engine testing applications. The 1PH8 is our lead product for these applications.

- Motor sizes: SH80–SH355
- Motor torque range from 13–12,475 Nm

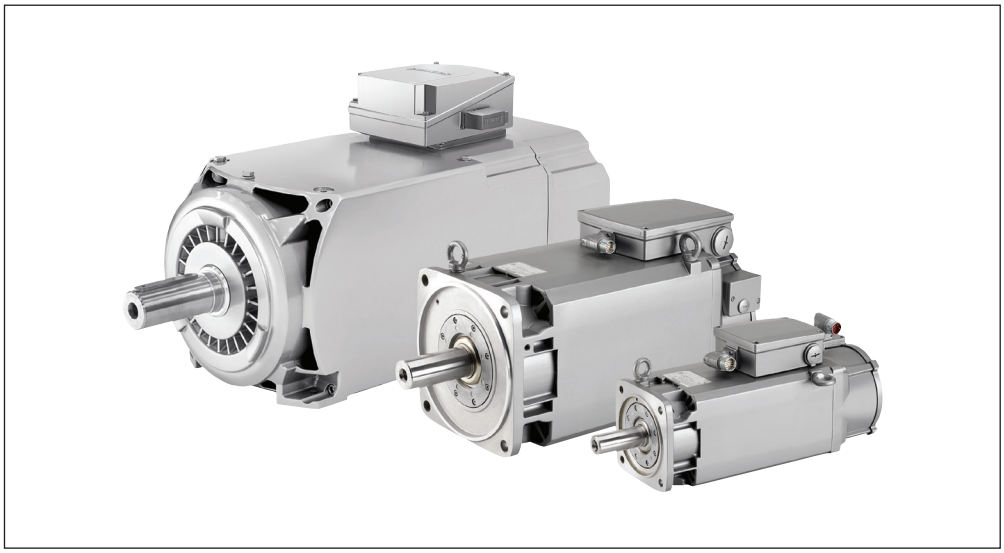


Figure 4

Custom motors

If the SIMOTICS M-1PH8 motor family doesn't meet the requirements, Siemens has options for other motors specialized for engine testing. Please contact your Drives and Motion Consultant for additional information.

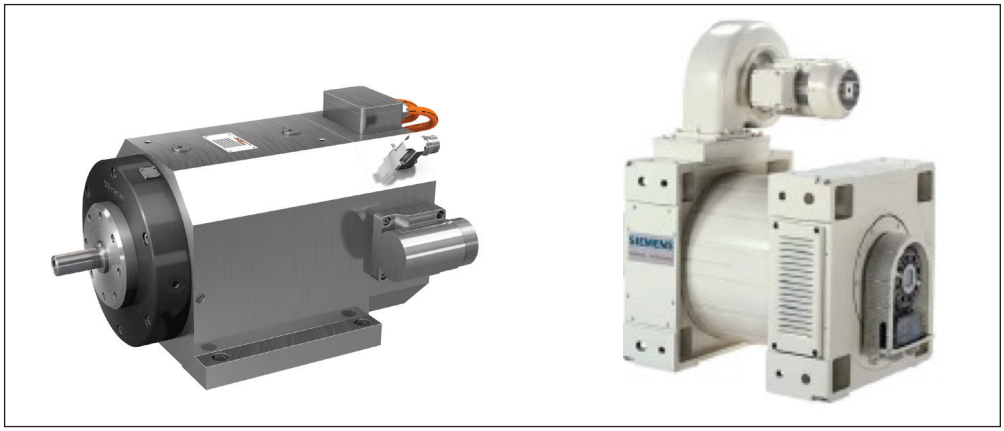


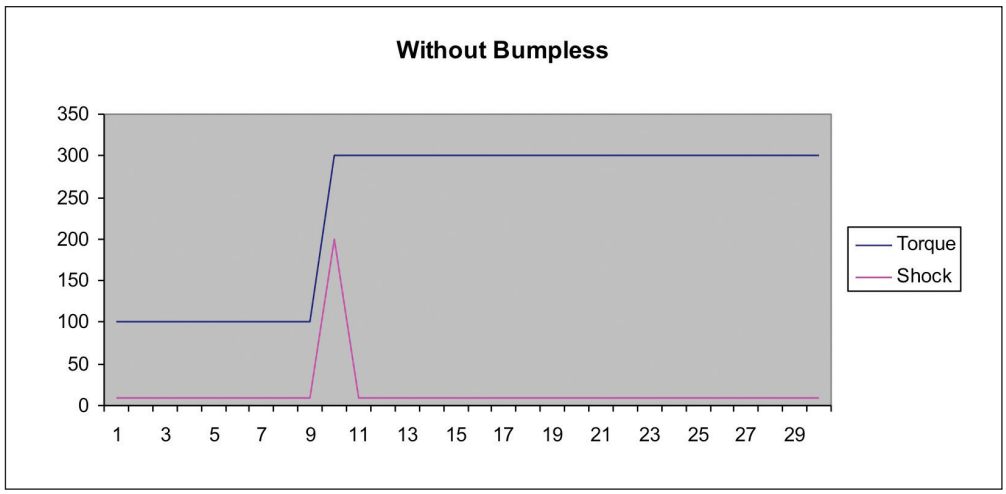
Figure 5

Bumpless transfer from speed to torque control

Used normally on hot test stands where the AC motor is used to turn over the engine, at some point the engine will start. Then the AC motor will need to switch from velocity control to torque control and act as an absorber.

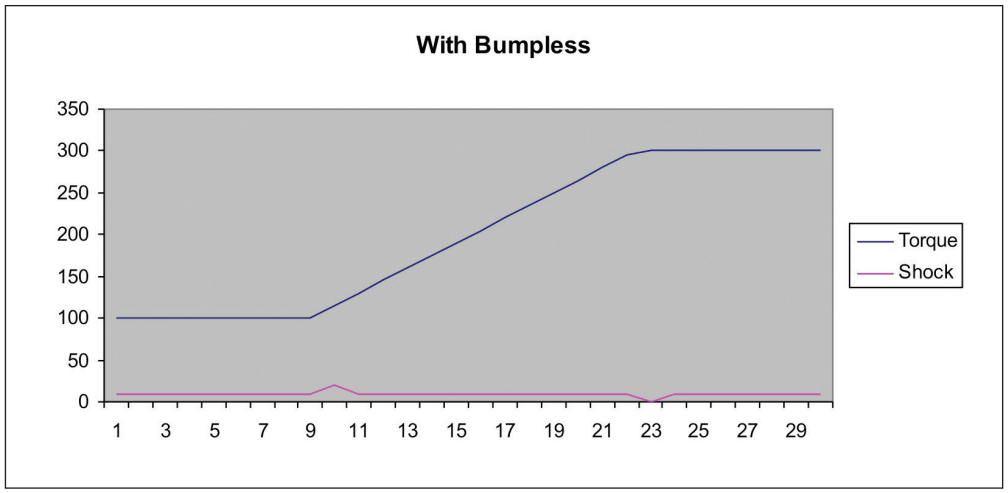
Usually, the drive needs “bumpless” transfer from speed to torque or torque to speed. This means the drive may need to go from speed- to torque-mode without causing a major disturbance.

Figure 6



With “bumpless” transfer, the torque output of the speed loop is sampled and set as the starting point to the torque, and then the torque reference is ramped gradually.

Figure 7



Torque transducer interfaces and torque estimator functions

In most cases, the customer will take the torque transducer back to a higher level controller (data acquisition) to close the loop (see Figure 8).

Another popular solution based upon performance or cost is a transducerless design. In this case, the drive line does not have a torque transducer and it uses current sensors in the drive to “estimate the torque output based upon motor parameters. Alternatively, the industry has a hybrid solution that still uses a torque transducer and uses the torque estimator function as a repeatable way to send a torque command. It also is a redundant torque feedback (see Figure 9).

Figure 8
Torque transducer is the primary measuring device. Optionally, the torque transducer can be spilt and used in the drive for better velocity regulation.

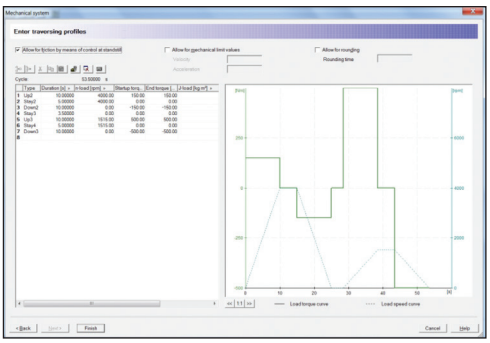
Figure 9
Torque transducer is removed and drive calculates drive-line torque.

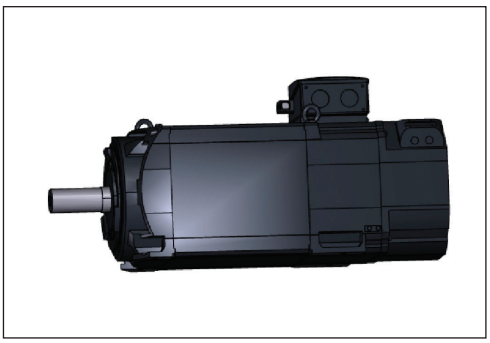
Siemens tools for test stand applications

SIZER

The main tool for applying Siemens drives and motors to test stands is SIZER. This allows an application engineer to generate speed-torque curves, dimension sheets, 3D motor models, along with data sheets for both the motor and the drive. It is a general tool for motor and drive dimensioning. Other motors upon request specific to test stand requirements.

Figure 10 left
Figure 11 right





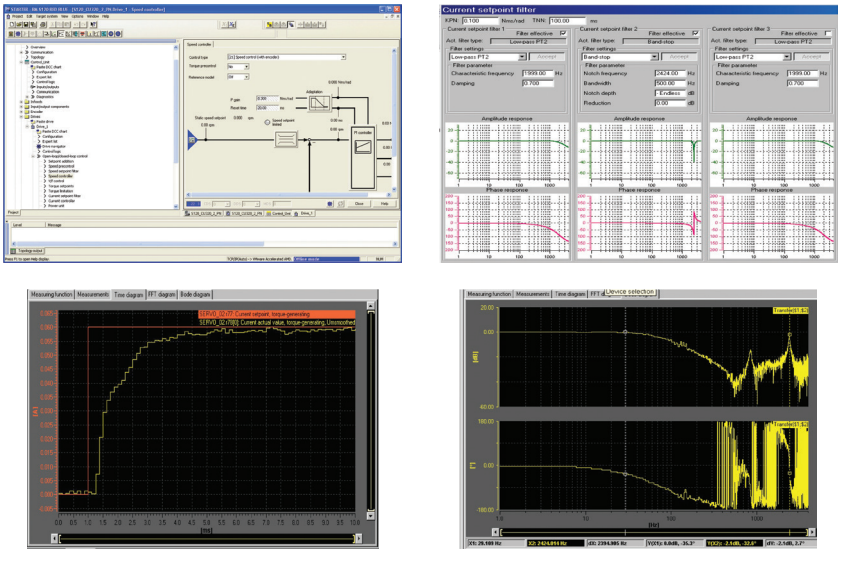
STARTER

The main tool used to start-up all SINAMICS drives is STARTER. This engineering tool is used to configure SINAMICS S- and G-series drives from very small up to very large drives online or offline.

Table 1

STARTER	
Feature	**Benefit**
Trace every drive in one trace	Efficient troubleshooting
Step response (current/velocity loop)	Auto, controller optimization
Bode plit diagram (drive-line response frequency)	Fast comminsioning and optimization
Filters — bandpass, notch, etc.	Open configuration

Figure 12



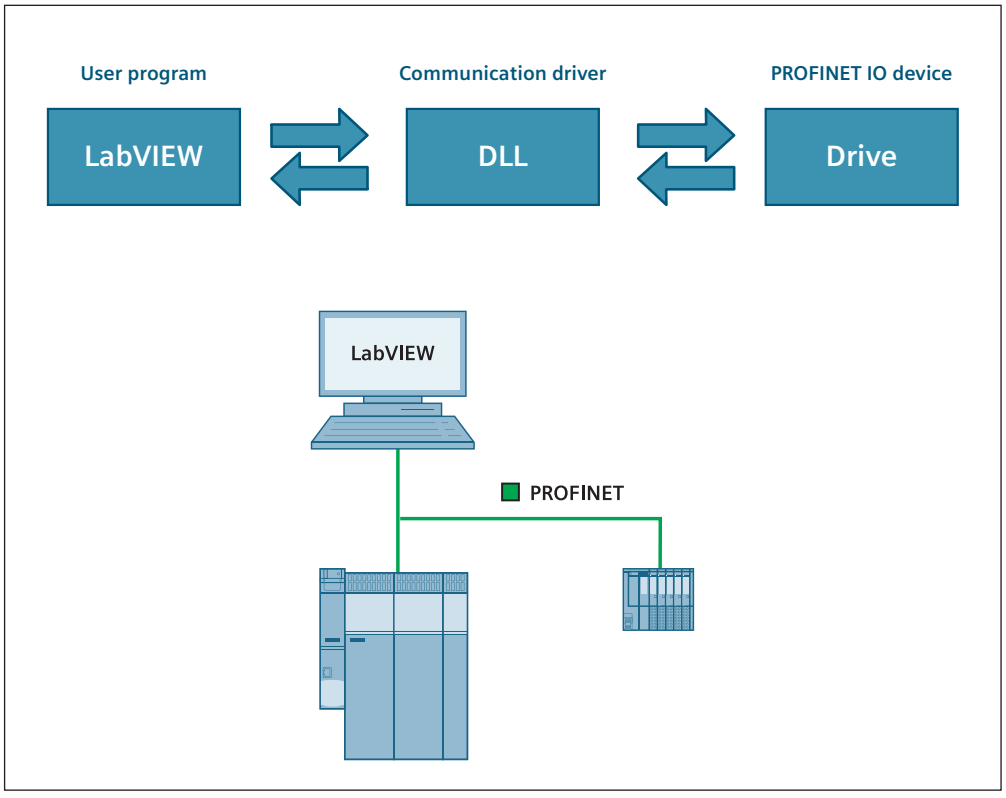
LabVIEW interface

Extended functions, not just a drive — the DLL (Dynamic Link Library) serves as the interface between the LabVIEW user program and the PROFINET IO devices. It provides functions, which control the communication and allow cyclic IO data to be transferred.

Table 2

LabVIEW interface	
Feature	**Benefit**
Standard telegram 1, 111 free configurabel	Predefined interface
Programmable logic and visulization on PC	No PLC or HMI necessary
PROFINET interface on ethernet interface	No additional hardware
Provided as a Siemens standard application	Download for free

Figure 13



Open architecture and drive control block / charts

SINAMICS drives include additional capabilities that are utilized in test stands — such as specific applications for powertrain testing. Torque Feed Forward (TFF), Engine Torque Pulse Simulation and a Set Point Generator, to name a few. These functions can be added to SINAMICS drives as an application or at the firmware level depending upon your requirements.

Table 3

Open architecture and drive control block/charts	
Feature	**Benefit**
OA — runs at current clock withing the drive	Very fast logic/control (µs)
DCB/DCC runs at 1ms	Fast logic inside the drive
OA polygon, OA setpgen, etc.	Presdefined and tested applications
Firmware function cogging torque compensation	Smooth torque with PSM

Figure 14
TFF with SINAMICS shows a better result (smooth velocity) as UNICO and Rockwell

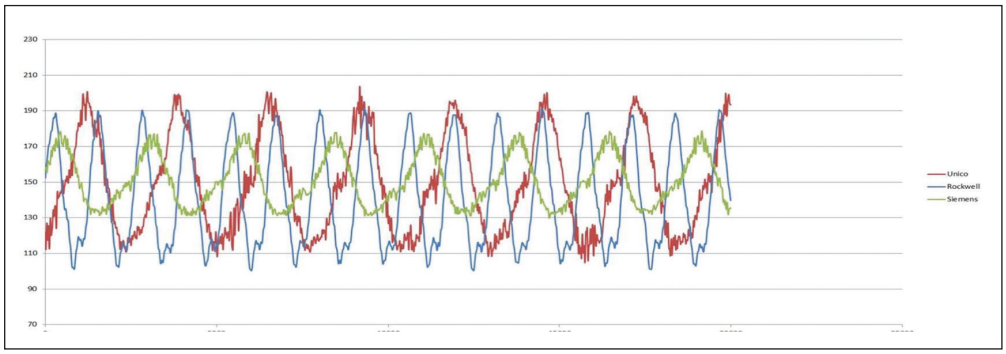


Figure 15
Without TFF +/-23 rpm

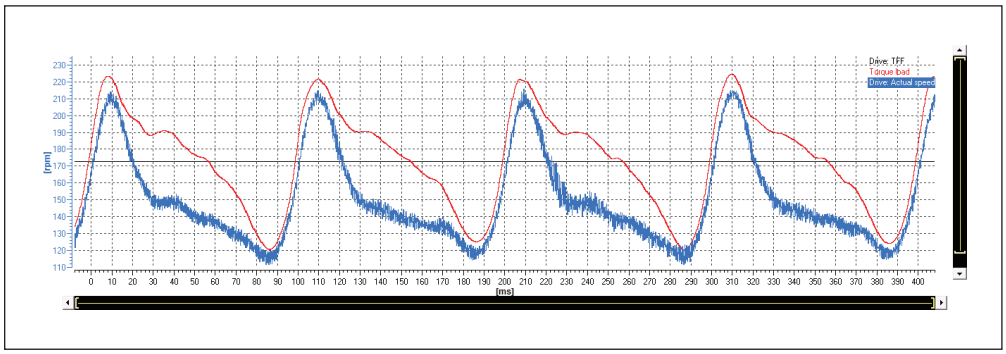
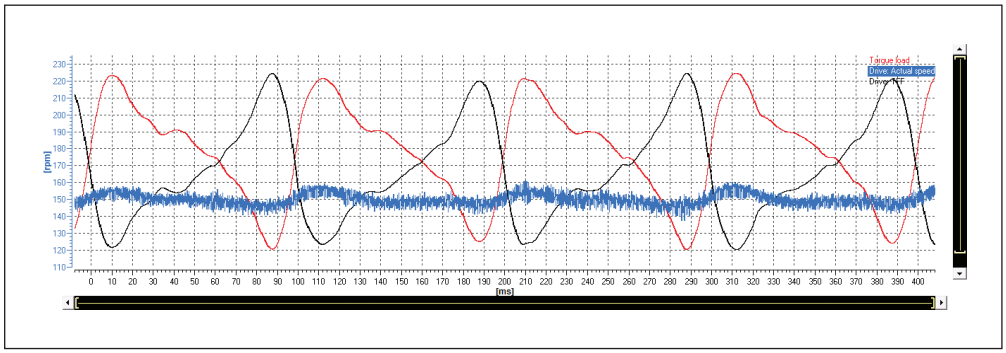


Figure 16
With TFF +/-6 rpm



Drive performance specifications

Booksize format, pulse frequency 4 kHz, closed-loop torque control

Table 4

	Servo control		Vector control	
Asynchronous motor	**1PH7 / 1PH8 without encoder**	**1PH7 / 1PH8 with incremental encoder 1024 S/R**	**1PH7 / 1PH8 without encoder**	**1PH7 / 1PH8 with incremental encoder 1024 S/R**
Controller cycle	125 µS	125 µS	250 µS	250 µS
Toral rise time (without delay)	–	0.8ms	2ms	1.2ms
	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above, up to rated speed.			
Characteristic angular frequency -3 dB	–	600 Hz	250 Hz	400 Hz
	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback.			
Torque ripple	–	1.5% of M_{rated}	2% of M_{rated}	2% of M_{rated}
	With encoderless operation in speed operating range 1:20, with encoder 20 rpm and above, up to rated speed.			
Torque accuracy	–	+/-3.5% of M_{rated}	+/-2% of M_{rated}	+/-1.5% of M_{rated}
	Measured value averaged over 3s. With motor identification and friction compensation, temperature effects compensated by KTY84 and mass model. In torque operating range up to +/-*M*rated. Approximate additional inaccuracy of +/-2.5% in field-weakening range. Servo: speed operating range 1:10 referred to rated speed Vector: speed operating range 1:50 referred to rated speed			

Competitive crossover

Table 5

	SINAMICS S120	Unico 2400 (2000)
Voltage V AC	200–240, 380–480, 500–**690**	200–240, 380–480, 500–660 (600–690)
Voltage variation	+/-10% **(-15%<1min)**	+/-10%
Line frequency	47–63 Hz	47–63 Hz
Output voltage	0 to line voltage **(0.7*DC link voltage ➞ 525 V, 700 V)**	0 to line voltage
Ouput frequency	**0–3200 Hz (Booksize)** **0–2400 Hz (HFD—High Frequency Drive)** 0–800 Hz (Chassis)	0–1000 Hz
Switching frequency	**1.25–32kHz** **16–32 kHz (HFD—High Frequency Drive)** 16 Hz (Booksize) 8 Hz (Chassis)	1Hz–20 kHz
Power factor	1.0 (-1.0 - +1.0)	0.94–0.99 (1.0)
Temperature	0–55° C **(over all power range)**	Up to 100 kW: 0–55° C Over 100 kW: 0–40° C
Site altitude	Up to **2000 m** without derating	Up to 1000 m without derating

Table 6

	SINAMICS S120	Unico 2400
AI		3x +/-10 V DC or 4–20 mA (12-bit)
AO		2x +/-10 V DC (12-bit)
DO		2
DI	**8**	
DI/DO	8	
Extension		
DI/DO		8
DI	4 (TB30), 4 (TM41)	2
DO	4 (TB30), 8 (TM31)	
AI	2x +/-10 V DC (13-bit signed), 1 (TM41)	
AO	2x +/-10 V DC (11-bit signed), 2 (TM31)	
DI/DO	24 (TM15), 4 (TM31), 4 (TM41)	32
Relay outputs	1	
Trasducer	Sin/cos, resolver, ABS (EnDat; SS), TTL, HTL, EnDat 2.1, DRIVE-CLiQ, PROFIBUS, PROINET	Sin/cos, resolver, ABS, EnDat, Hiperface, TTL

Table 7

	S120 Booksize (up to 250 kW)	S120 Chassis (250 kW+)	Unico 2000
Position control			
Bandwidth	Depends on the mechanic	Depends on the mechanic	100 Hz
Velocity control			
Bandwidth	250 Hz at 4 kHz with transducer	250 Hz at 4 kHz with transducer	200 Hz with transducer
	50 Hz without transducer	50 Hz without transducer	10 Hz with transducer
Regulation	<=0,001%	<=0,001%	±0.001% of base speed with transducer
Torque control			
Banswidth	Up to 2000 Hz (➞ high dynamic)	900 Hz	600 Hz
Regulation	+/-1.5% of MO without transducer 12-bit current measurement	+/-1.5% of MO without transducer 12-bit current measurement	±2.0% of maximum torque without transducer

Other key features

SINAMICS drives and SIMOTICS motors for motion control

- Complete Siemens solution with SINAMICS G- and S-series drives, SIMOTICS S-1FK7 servomotors and SIMOTICS M-1PH8 main spindle motors
- One drives family for all applications — up to 4500 kw
- Common hardware architecture
- Easy drive / controller-based solution
- Motor identification through DRIVE-CLiQ interface
- EtherNet / IP-compatible
- Integrated web server for easy monitoring and custom web pages
- Reduced panel size increases floor space
- Common hardware architecture
- Backup of complete project with Compact Flash (CF) card
- Easy-to-use SIZER and STARTER software for commissioning — free-of-cost
- Safety first
  - ProfiSafe for Safe Torque Off or Safe Motion (if required)
- Siemens expertise and technical competence in test stands
  - Experienced in current / velocity loop tuning, drive-line resonances
  - Battery simulation and hybrid test stand solutions
  - Global customer references
- Worldwide support structure

Figure 17
SINAMICS drives family

Glossary

Speed regulation

Ability to control speed accurately, typically within .1% of commanded velocity.

Torque regulation

Ability to control torque accurately, typically within 2% of commanded torque.

Bumpless transfer

Ability to switch from torque to speed smoothly, or vice-versa.

Torque transducer

A rotary device in the drive-line that accurately measures torque, typically .1% or better.

Torque estimation

A drive measured value based upon motor current and temperature, sometimes used as the primary measuring device, >2% accuracy required.

Signature analysis

During testing, either speed values (speed signature) or torque values (torque signature) are captured and collected with a data acquisition computer. The values are used to determine if the tested component meets the range of a known good (master component).

Data acquisition

The process of sampling signals that measure real-world physical conditions and converting the resulting samples into digital numerical values that can be manipulated by a computer.

NVH testing

Noise, vibration and harshness testing in one process, typically done in differential testing to measure noise coming from gear mesh.

EOLT

End-of-line testing is performed during the last step of the assembly to measure and validate if the end-product was assembled correctly and passes its required tests.

In-process testing

Testing during the assembly process, also sometimes referred to gauging.

DC bus sharing

Allows for drives to share energy and power during the testing process, used in multi-axis testing where you have input and output motors.

Regenerative line module

Allows for DC bus energy to be converted to clean AC power and put back to the main power lines. Used mostly in engine testing where the AC motor is acting as a load.

Torque ripple

A periodic increase or decrease in output torque as the motor output shaft rotates. It is measured as the difference in maximum and minimum torque over one complete revolution, generally expressed as a percentage.

Speed sweep

A testing procedure where torque is held constant and speed is varied with a specific ramp and profile.

Torque sweep

A testing procedure where speed is held constant and torque is varied with a specific ramp and profile.

Customer references

Table 8

Machine type	Manufacturer
Transmission testing machines	ATS, BEP, Blum, Dynamic Assembly Machines, Dynaspede, Eutomation Scansys, Kleinknecht, Renk, Seichter, teamtechnik, TES VSETIN, Thyssen, ZF
Transmission test, 1PL6 motors	GM for Mahindra & Mahindra, India
8-speed transmission, Masterdrive	ZF Chrysler Kokomo
9-speed transmission, (4) Masterdrive, (4) S120	ZF Passau Greenville
Tire testing machines	Alpine, ATT, Makra, Metal Tech, ZF
Combust engine testing machines	Bratz, Caterpillar, D&V, Dynaspede, FEV, Kleinknecht, LUK, Paccar
Combust engine cold-testing machine	ATW, FCA, Ford, Froehlich, GM, ThyssenKrupp
Engine cold test, S120/1PH8	Techno for Opel — Szentgotthard, Hungry
Engine test	CAT China — Digitek China, LUK
Engine hot test, S120 Drives, 1FW torque motors	FEV for Paccar
Engine test stand	Techno Germa
Hybrid engine test	IVD
Driveline testing	BLUM, GKN, Novotest, Schenck, Thyssen, TS
Drivetrain test	GKN
Battery simulation	Kristl & Seibt, Maha, team technik, ZF
Roller dynamometer test bench	AZL, Burke E. Porter, Dürr, Horiba, Ipetronik, Maha, SAR, Sun electric
Interior testing	Berghof, Kübrich
Generator testing	Continental, Bosch
In-process testing/balancing	ATW, BTI, Dana, FCA, Ford, GM, MP Balance Engineering, ZF
Helicopter gearbox	Red Viking

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Order No. DRBR-AUTTS-0615

Printed in USA

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