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Rotational Measurements with Resolvers energize the input phase with TSB582

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Product Marketing Engineer

General Purpose Analog

Agenda

1 Rotary resolver operation

2 Angular position solution
- TSB582 – Primary coil excitation
- TSB514 – sine/cosine output signal conditioning
- STM32 Nucleo – RDC processing

2 Application examples

3 Demo overview

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Rotary position sensors

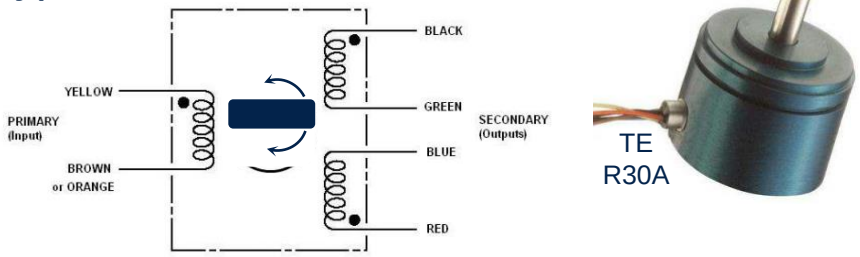
Non-exhaustive list of common sensing methods

Active electronics

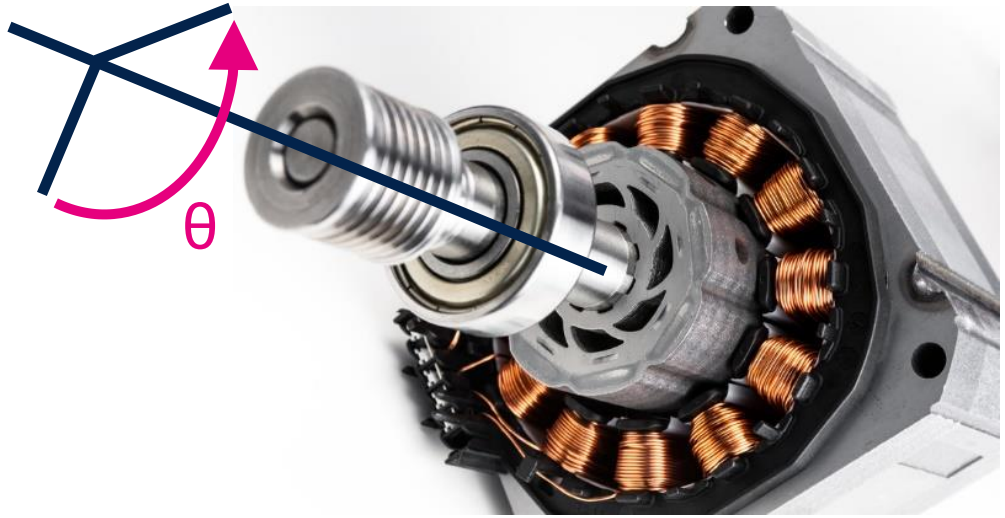
Encoder – Optical

Linear over limited range

Inductive – RVDT – Rotary Variable Differential Transformer – rotor and stator both made of ferromagnetic metal. Only stator incorporates windings (one primary and two secondary)



Determine the angular rotation θ of a shaft



Resolver – An electrical transformer used to measure angle of rotation. Resolvers generate a voltage corresponding to absolute angular position due to the interaction of magnetic fields of the rotor and stator. Suitable for use in extreme temperature, shock, and vibration, and harsh conditions (dust, humidity, oily)

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Resolver mechanical options

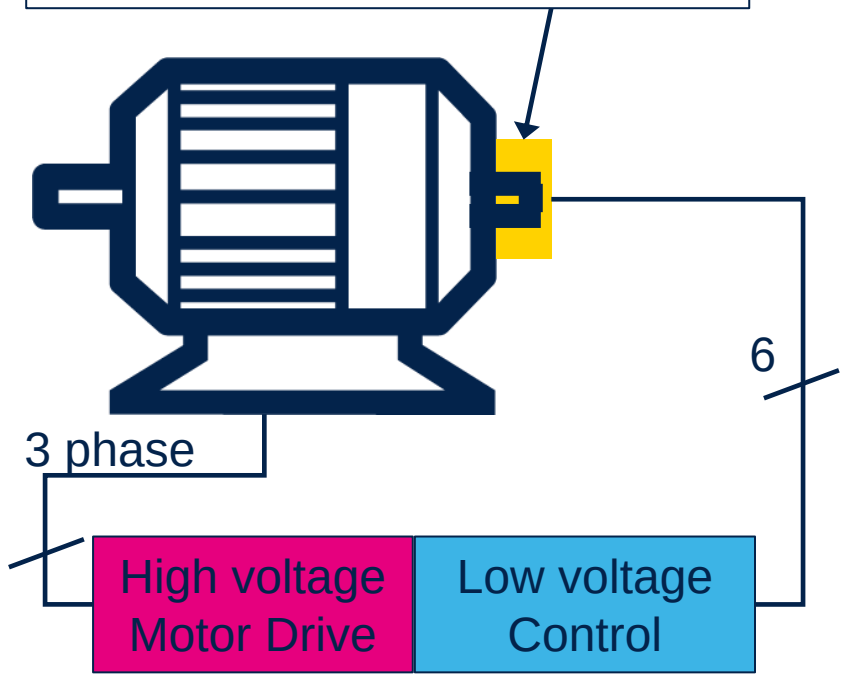
Housed Resolver

Dynapar R25

Frameless Resolver
Hollow Shaft

TE Connectivity
V23401- S1001-B110
10KHZ, 7VRMS

Resolver mounted to back face of motor in high temperature, high vibration environment where an encoder will not work.



The Rotary Resolver includes two basic components:

- Stator - stationary part
- Rotor - revolving part – attached to spinning shaft

Low voltage control electronics mounted remotely, with motor controller.

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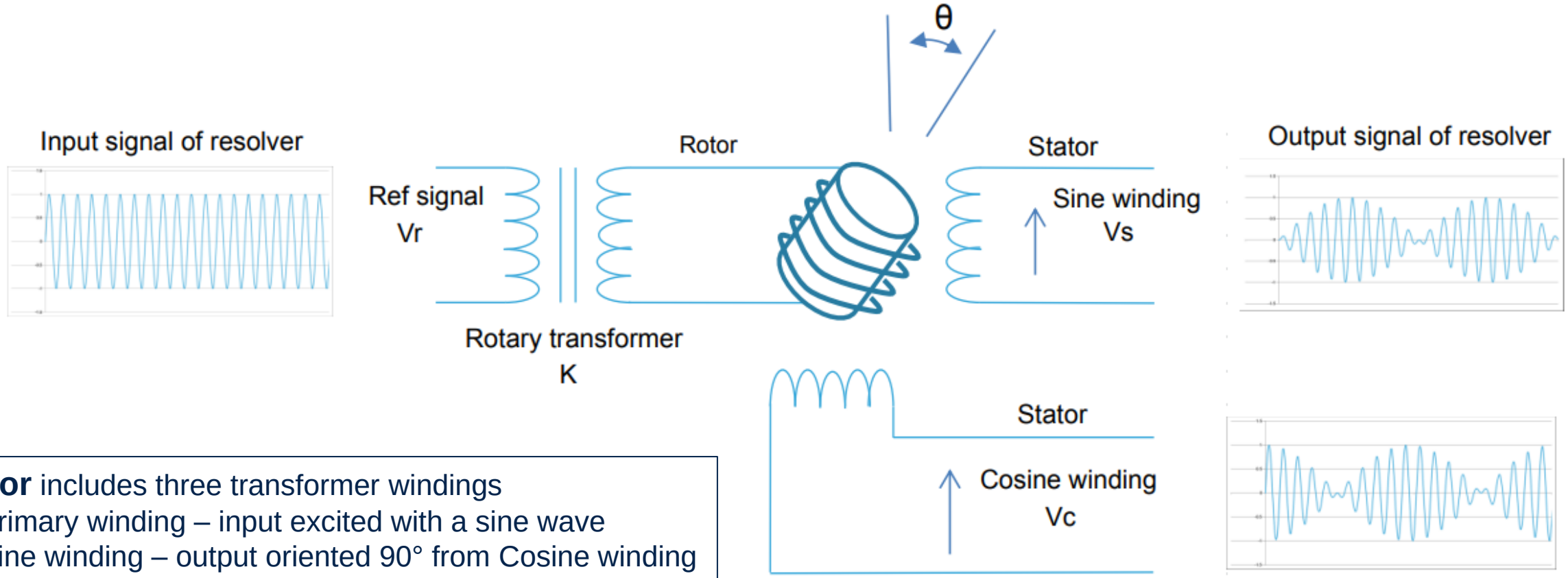
Resolver operation (1)



Stator includes three transformer windings
- Primary winding – input excited with a sine wave
- Sine winding – output oriented 90° from Cosine winding
- Cosine winding– output oriented 90° from Sine winding

Rotor includes two transformer windings
- Secondary winding – couples signal from Primary winding on the Stator
- Reference winding – coupled to Sine and Cosine windings on the Stator

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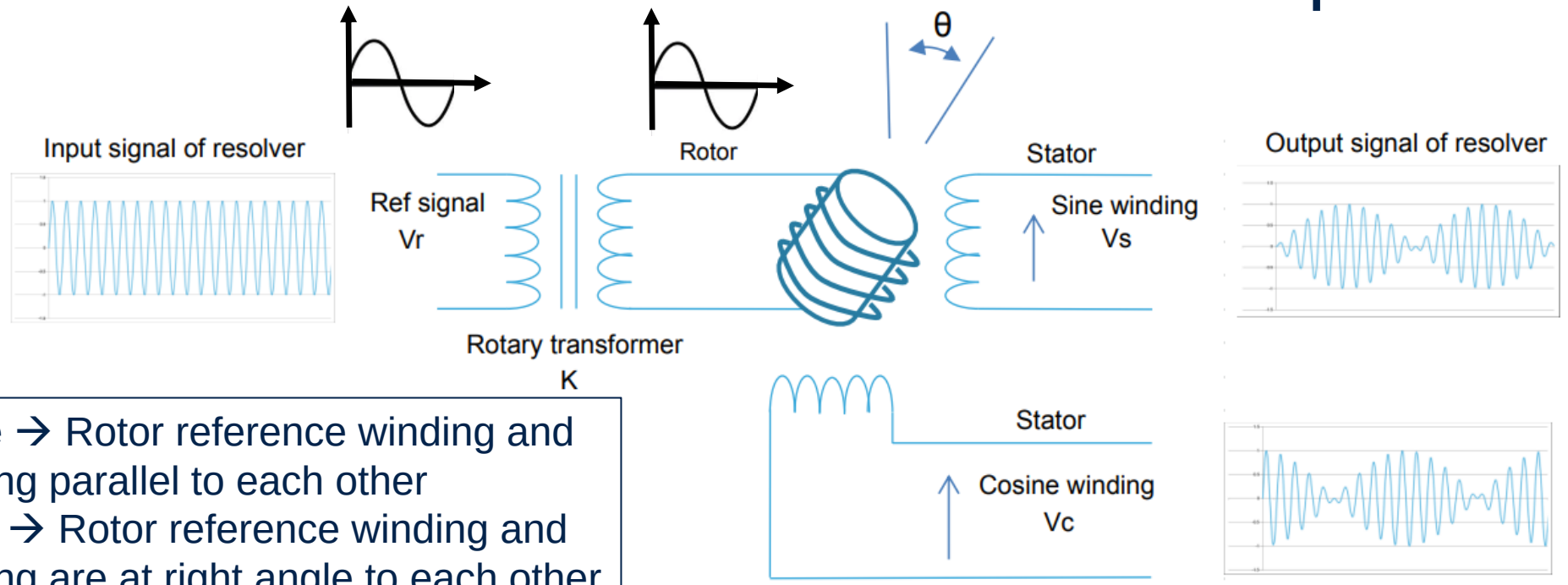
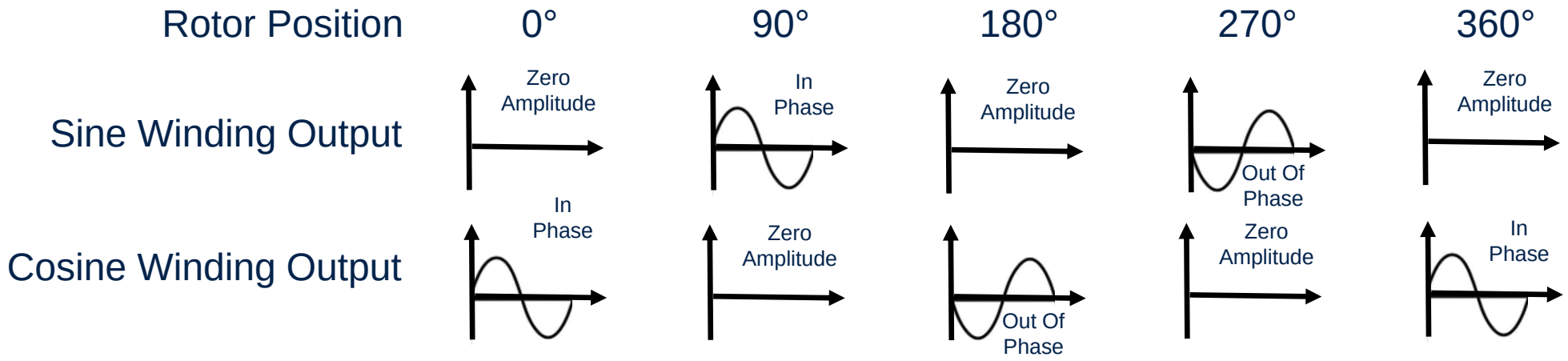
Resolver operation (2)



Peak Amplitude → Rotor reference winding and measuring winding parallel to each other
Zero Amplitude → Rotor reference winding and measuring winding are at right angle to each other



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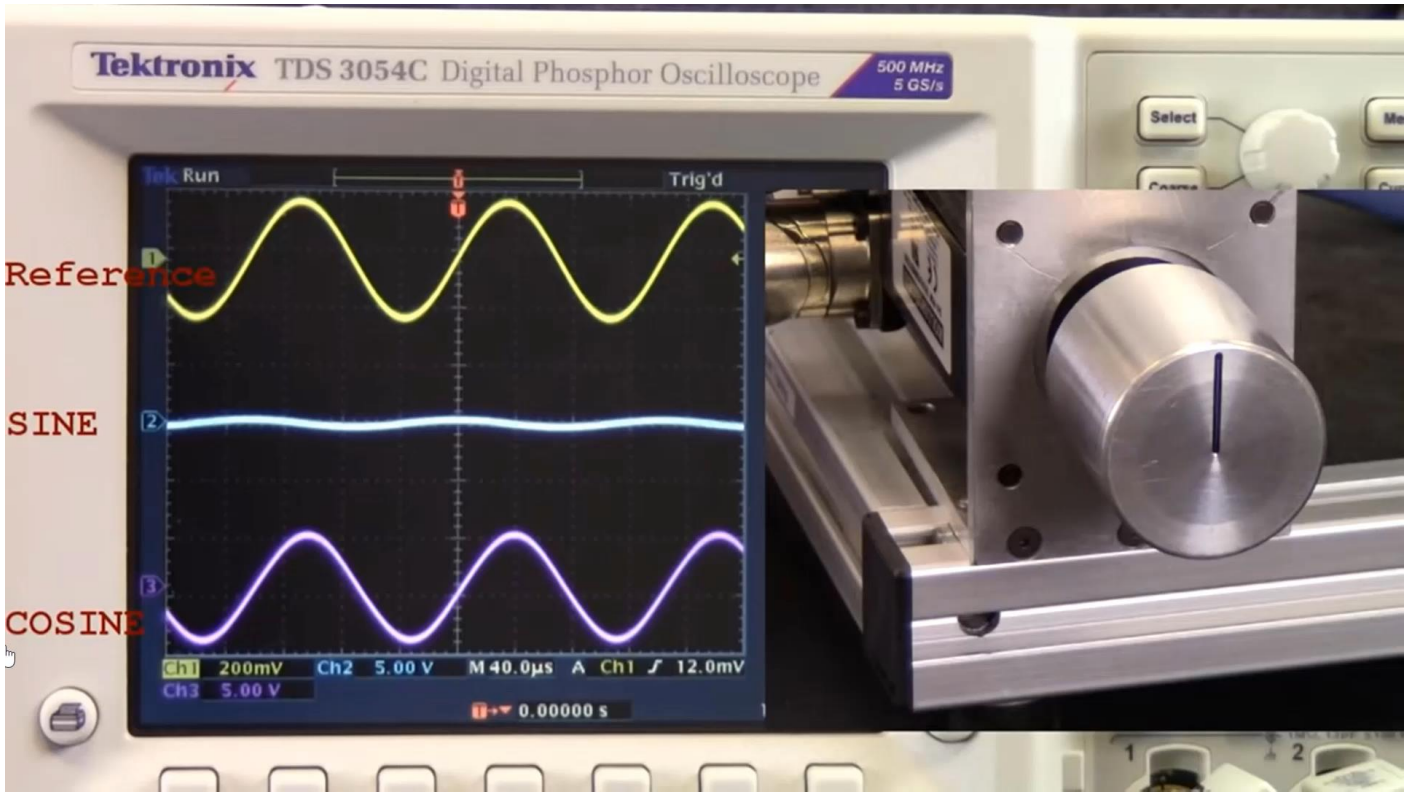
Resolver operation (3)



Link to the full video:

YouTube

Rotor Position	0°	90°	180°	270°	360°
Sine Winding Output	Zero Amplitude	In Phase	Zero Amplitude	Out Of Phase	Zero Amplitude
Cosine Winding Output	In Phase	Zero Amplitude	Out Of Phase	Zero Amplitude	In Phase

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Resolver construction

Single speed resolver

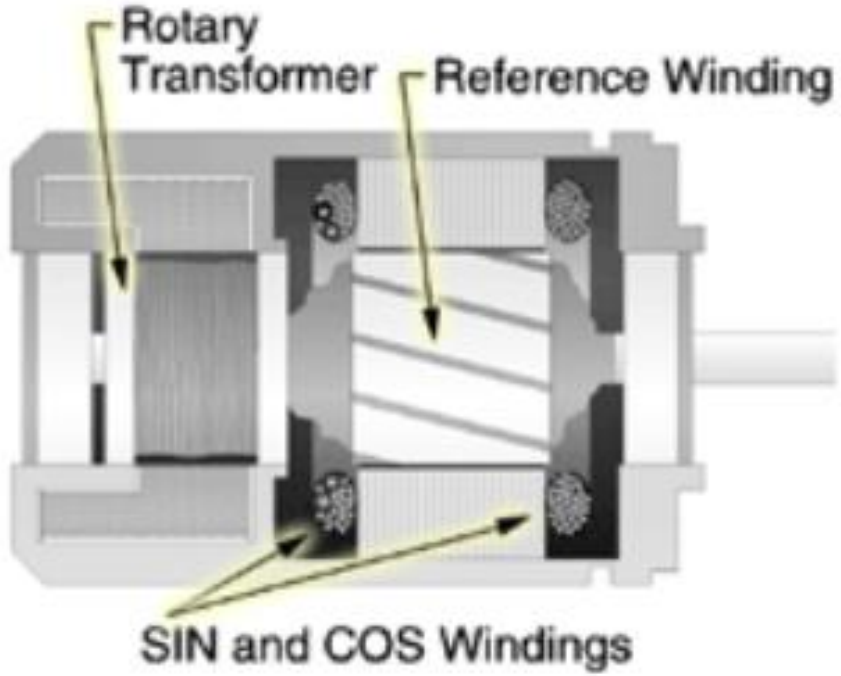
- Integrates 1 pair of Sine/Cosine windings in the stator

Multiple speed resolver

- Integrate 2p pair of Sine/Cosine windings in the stator
- Delivers p cycles of Sine/Cosine waves in one rotor rotation
- Provides p times higher resolution and accuracy

Example:

- p = 8
- Stator will have 16 sets of Sine and Cosine windings
- Resolver delivers 8 signals
- Provides 8x accuracy versus a single speed resolver



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Note: Multiple speed resolvers do not provide absolute position. Need to mount a single speed resolver on the same shaft to provide absolute position.

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Resolver spec sheet

TE Connectivity
V23401- S1001-B110
10KHZ, 7VRMS

PN	2-1393047-5			
Description:	V23401		S1001-B110	
Size	15			
Shaft inner diameter [mm]	9,52 H8			
Speed - pair of poles - [pp]	1			
Application Spec				
Test protocol	100% EOL testing, stored. Available up on request			
Electrical parameters (at 22°C):				
Input voltage nom. [Vrms]	7	possible 2V...8V	DC resistance R1R2 [Ω]	82
Frequency nom. [kHz]	10	pos, 4kHz...20kHz	R1R2 tolerance [±Ω]	8,2
Input current max [mA]	40	Based on nominal Input voltage and Frequency	DC resistance S1S3 or S2S4 [Ω]	68
Transformation ratio rT [±]	0,5		S1S3 or S2S4 tolerance [±Ω]	6,8
Transf. ratio tolerance [%]	4			
Phase shift min [º]	-2			
Phase shift max [º]	8			
Angular Error [±']	6			
Residual voltage max [mV]	25			
Connect. Wire Lenght [mm]	470, AWG 26 Teflon Isolated			
Max. Rotational Speed	20.000 rpm			
Shock resistance (11ms sine)	1.000 m/s2			
Vibration (0 ... 2 kHz)	200 m/s2			
Operating temp.	-55°C...+150°C			

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Resolver excitation with TSB582

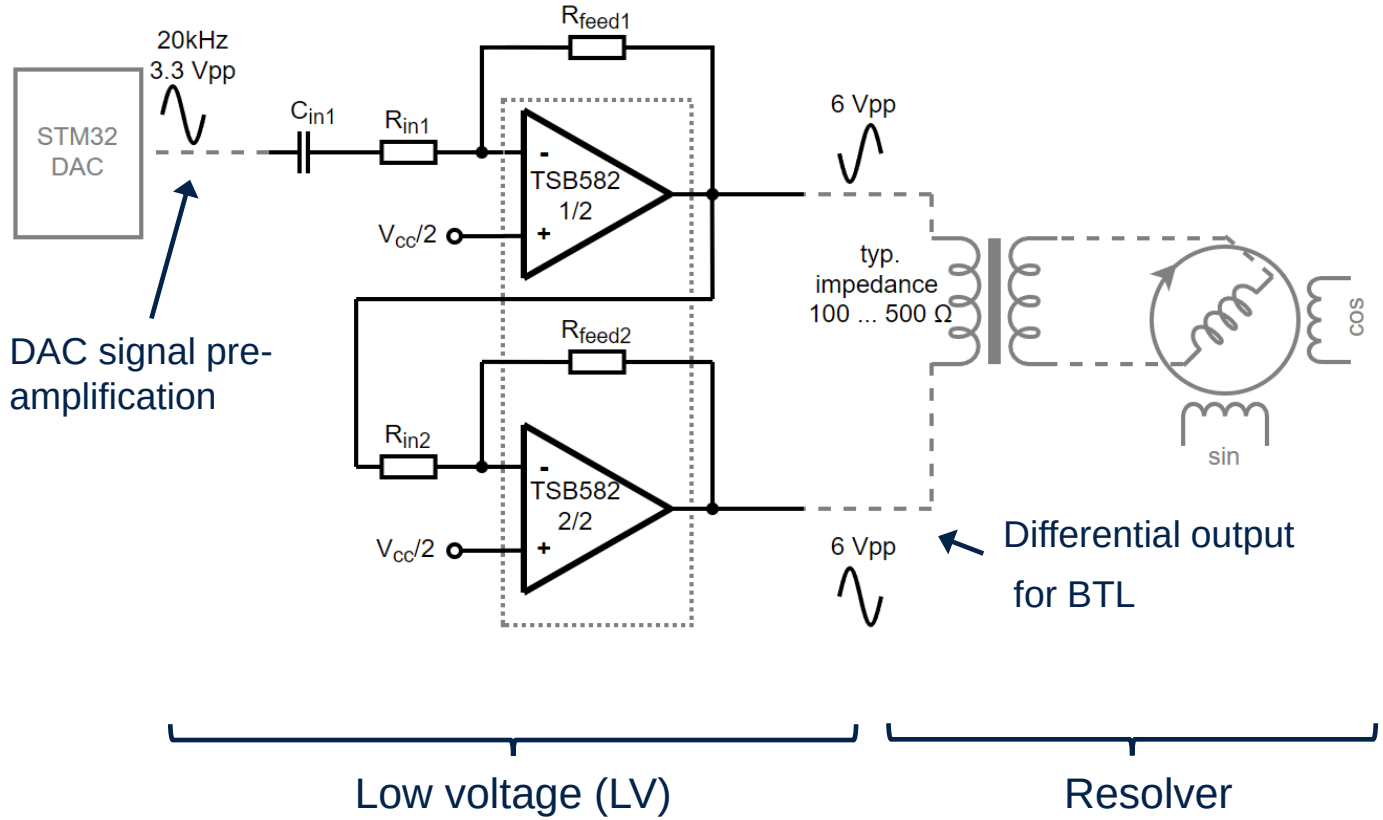
Resolver excitation

Typical input voltage to Stator Primary winding
- 4VAC to 26VAC

Typical reference wave frequency
- 50 to 60 Hz for industrial / utility
- 400 Hz for marine
- 3 kHz to 10 kHz aerospace / military

Typical current to Stator Primary winding
- in excess of 100mA

Working in bridged mode



TSB582 detail

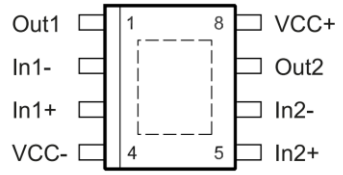
200mA output current, 36V dual operational amplifier

High output current
- 2x 200mA (typ) with internal protection

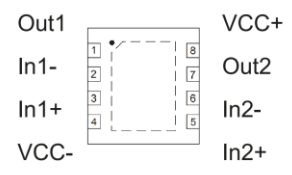
Flexibility
- Operating power supply range 4V to 36V
- Fully dynamic rail-to-rail outputs
- 3.1MHz GBW
- Extended temperature range: -40°C to +125°C

Thermally conductive packages
- SO8 exposed pad and QFN8 wettable flank for automotive
- Excellent R_{thja} through exposed pad (40~45 °C/W)

Robustness
- Integrated thermal shutdown and current limiter
- Integrated EMI filter
- 4kV HBM ESD tolerance
- Automotive grade available



SO8



DFN8 (3 x 3)

Name	Pin Name	Description
OUT1	1	Output channel 1
IN1-	2	Inverting input channel 1
IN1+	3	Non-inverting input channel 1
VCC-	4	Negative supply voltage
IN2+	5	Non-inverting input channel 2
IN2-	6	Inverting input channel 2
OUT2	7	Output channel 2
VCC+	8	Positive supply voltage

TSB582 block diagram

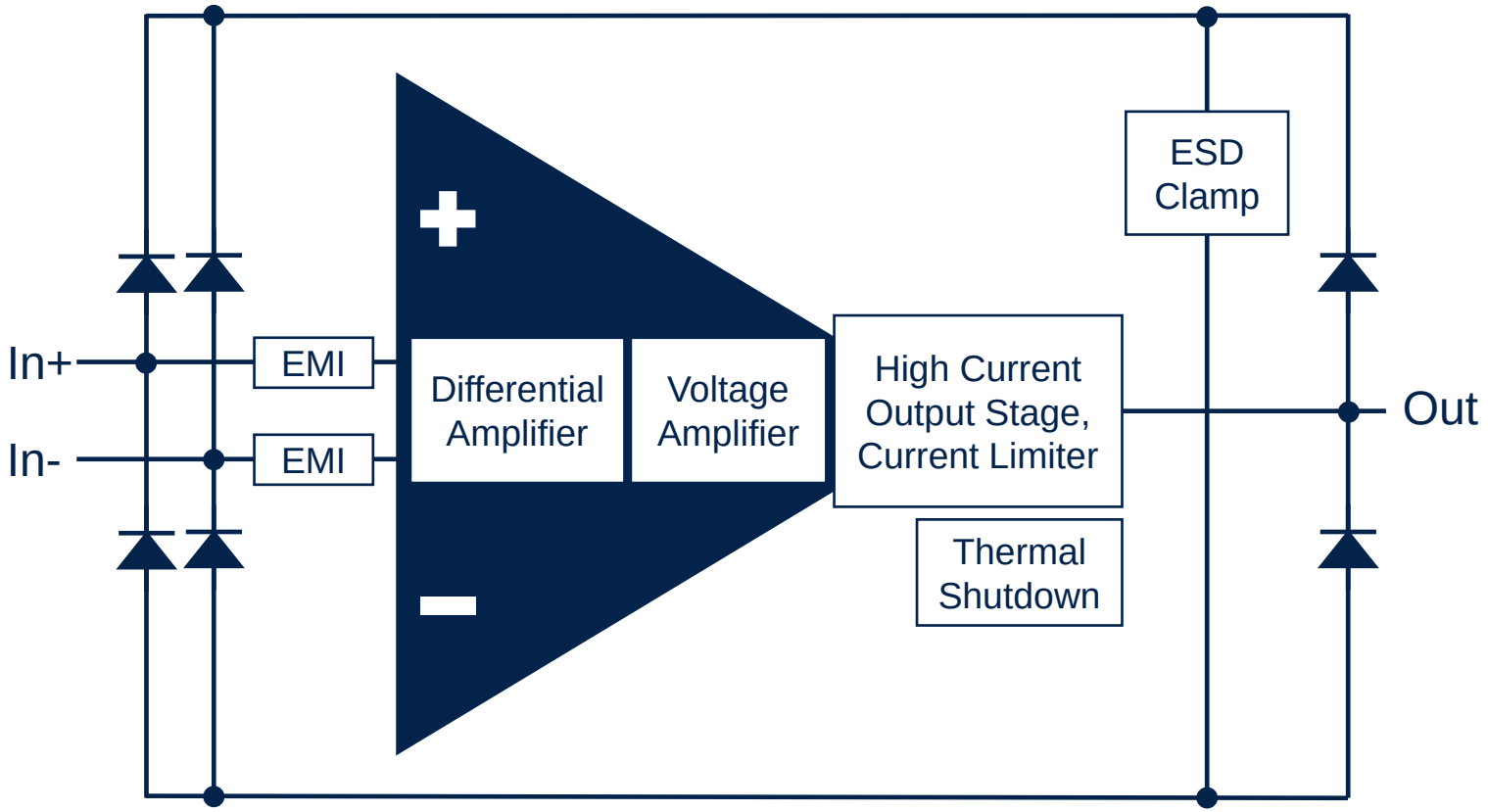
Technology and design achievements for enhanced performances and protection

Key features → benefits

Protected high current outputs
→ integrated current limitation
→ integrated thermal shutdown

ESD and EMI protection
→ 4kV HBM
→ 55dB EMI rejection @ 400MHz

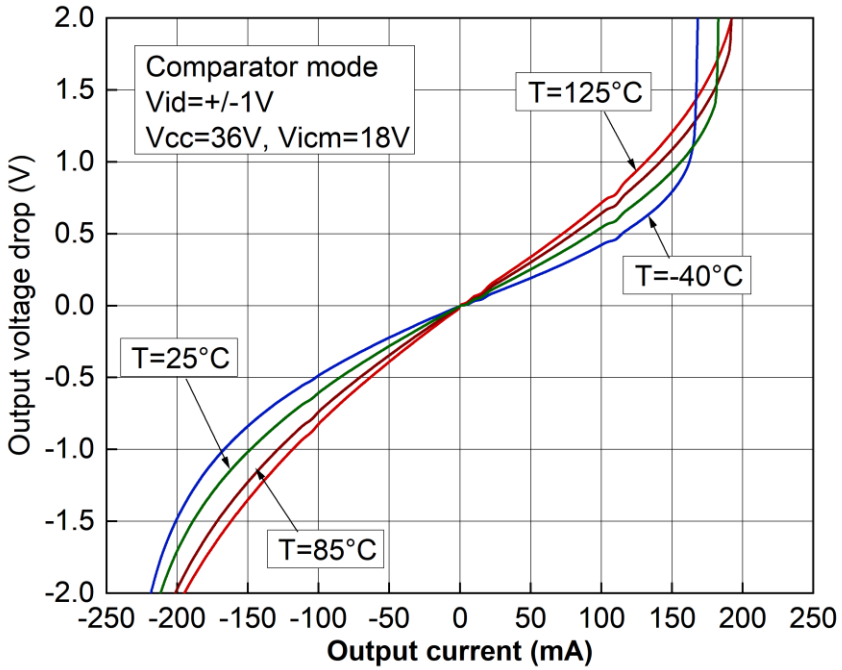
Small package dimensions
→ SO8 exposed pad
→ DFN8 wettable flank



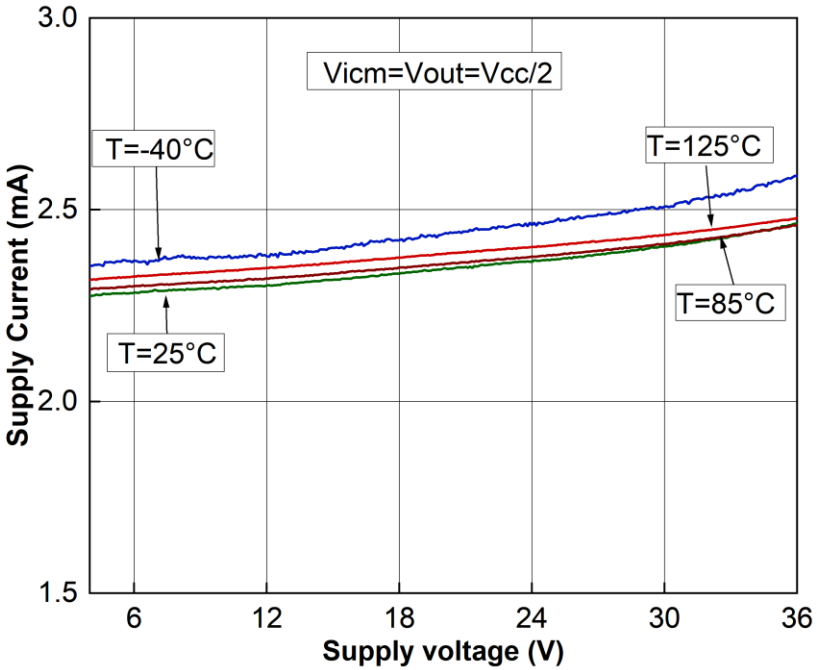
TSB582 performance

Excellent output current characteristics with low power consumption

Output voltage drop vs. output current



Supply current vs. supply voltage



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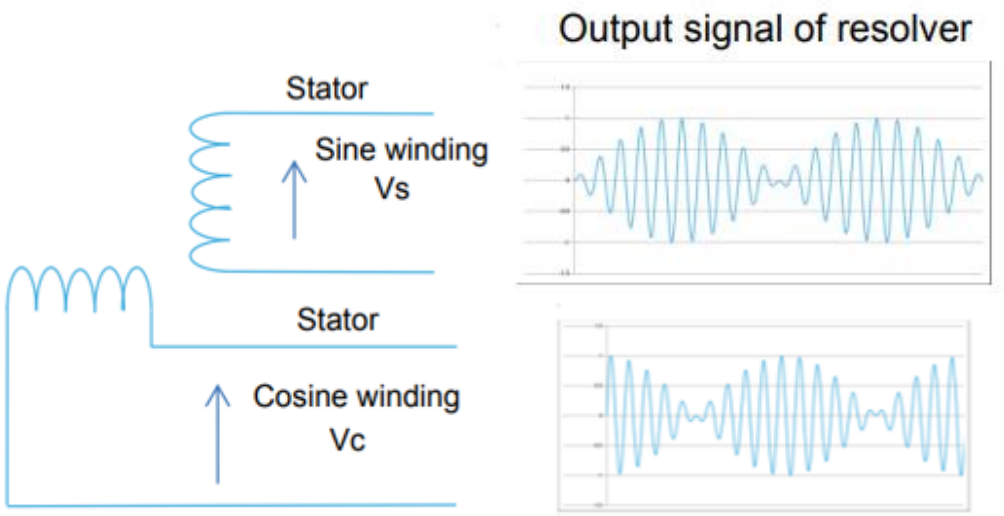
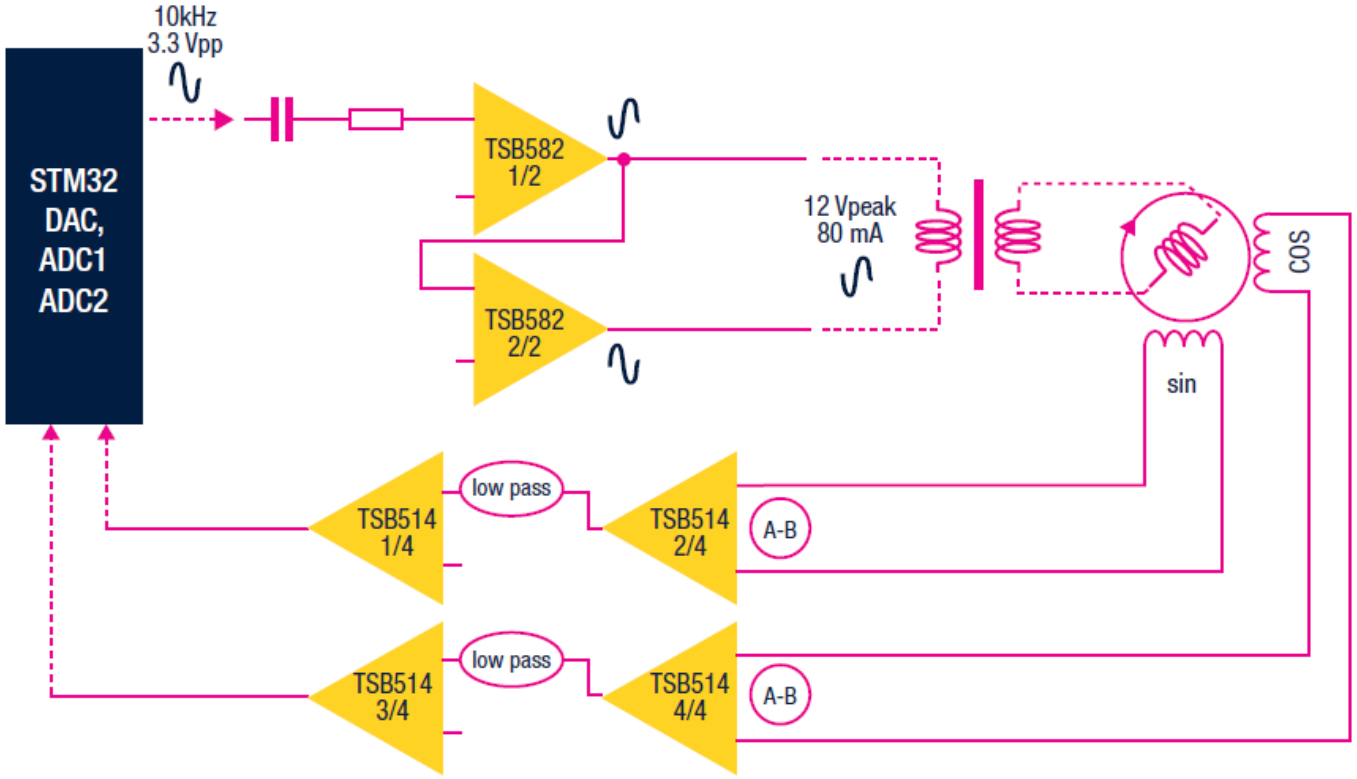
Signal Conditioning with TSB514

Sine / Cosine signal conditioning





TSB514 detail

Rail-to-rail inputs and outputs, 36 V, 6 MHz op-amps

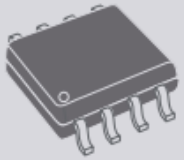
TSB514

TSSOP14

SO14

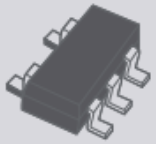
TSB512

MiniSO8



SO8

TSB511



SOT23-5

EXTENDED OPERATING RANGE

- Temperature range from -40°C to 125°C
- Wide supply voltage from 2.7V to 36V
- Rail-to-rail Input and Output

HIGH SPEED FOR APPLICATIONS WITH FAST SIGNALS

- Gain Bandwidth Product: 6 MHz
- Slew Rate: 3 V/us
- Low noise: 12nV/√Hz typ.

ROBUSTNESS

- Integrated EMI filter
- 2kV HBM ESD tolerance
- Automotive grade available

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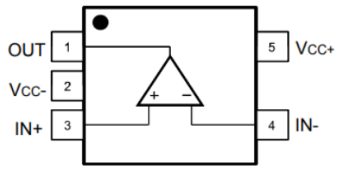
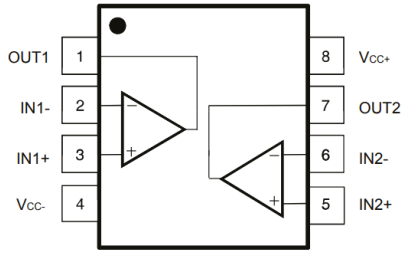
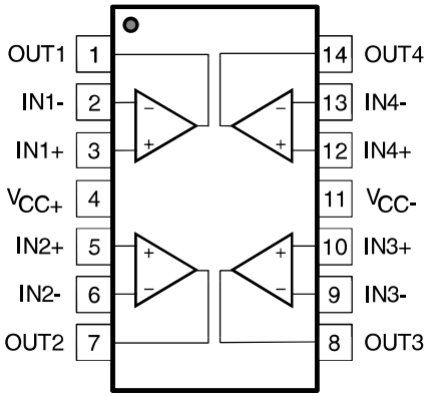
TSB514 part numbers and pinout

Rail-to-rail inputs and outputs, 36 V, 6 MHz op-amps

		Industrial	Automotive	
Quad	TSSOP14	TSB514IPT	TSB514IYPT	AG
	SO14	TSB514IDT	TSB514IYDT	
Dual	MiniSO8	TSB512IST	TSB512IYST	AG
	SO8	TSB512IDT	TSB512IYDT	
Single	SOT23-5	TSB511ILT	TSB511IYLT	AG

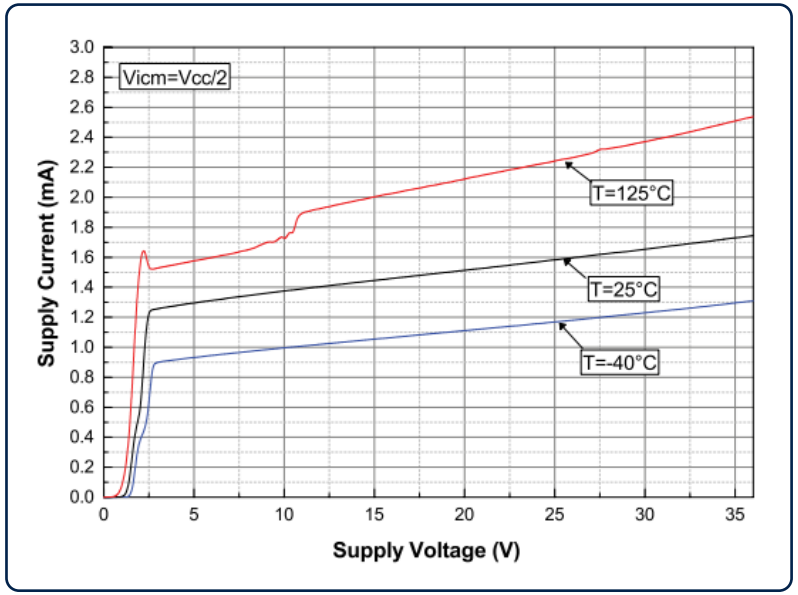






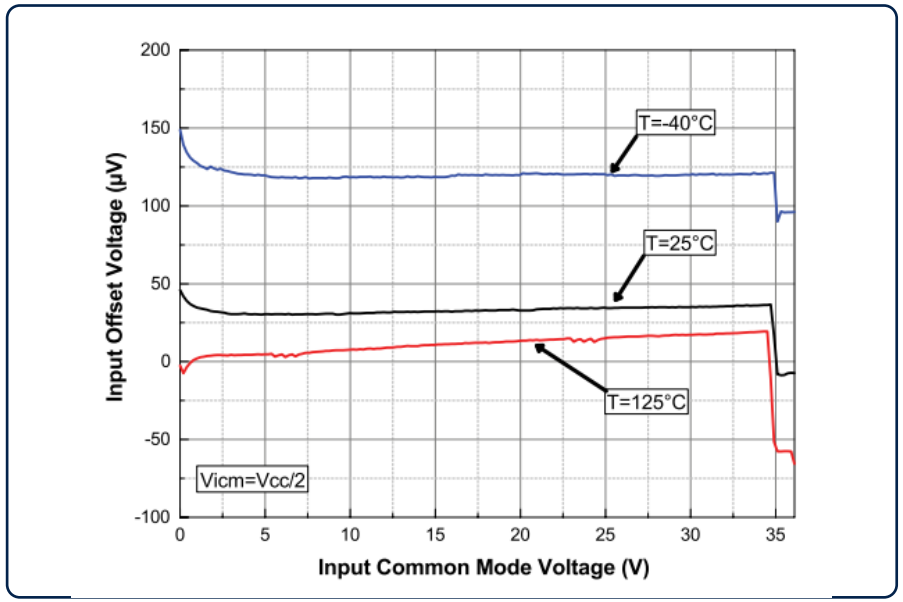
TSB514 performance

TSB514 for high voltage and fast signal conditioning

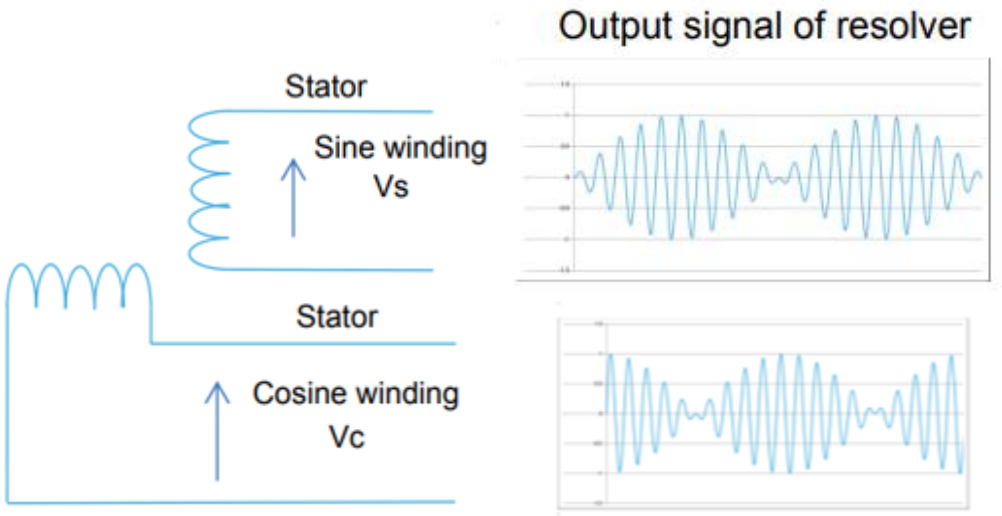


Supply current vs. Supply voltage

Rail to rail inputs
with Vio behavior



Resolver-to-Digital RDC



Resolver-to-Digital conversion

A way to measure the relative magnitudes of the two-phase voltages in the stator and digitize to determine the Rotor angle

RDC can be implemented in function-specific IC, or software based

RDC – Trigonometric versus PLL

Trigonometric method, also known as arctangent method, is simple and easy to implement.

$$V_r = A0.\sin\omega t$$

Describes input reference signal
A0 is the amplitude of the input signal
ω is the resolver driving frequency

$$V_S = K * V_r * \sin\theta$$
$$V_C = K * V_r * \cos\theta$$

Describes sine/cosine generated voltages
K is the transformation ratio
θ the rotor angle

$$\theta = \mathrm{Atan}\left(\frac{Vs}{Vc}\right)$$

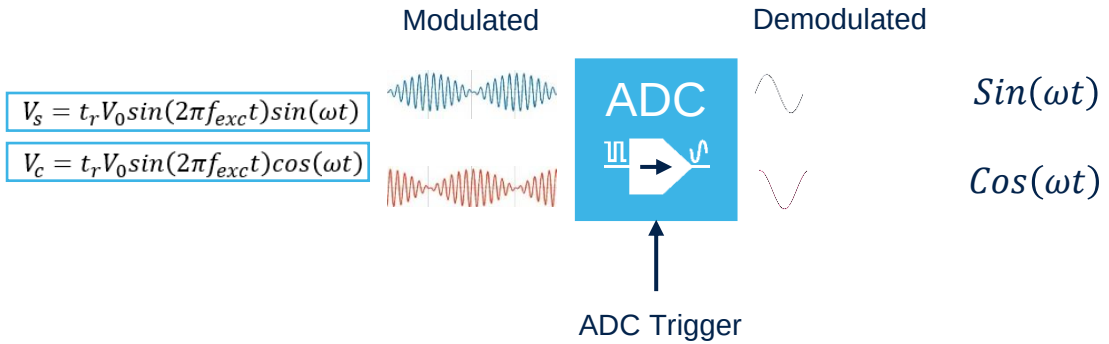
Trigonometric method only yields the rotor position (θ). Rotor speed (ω) is obtained by a differential operation to rotor position which can amplify noise in the resolver signals and cause large estimation error.

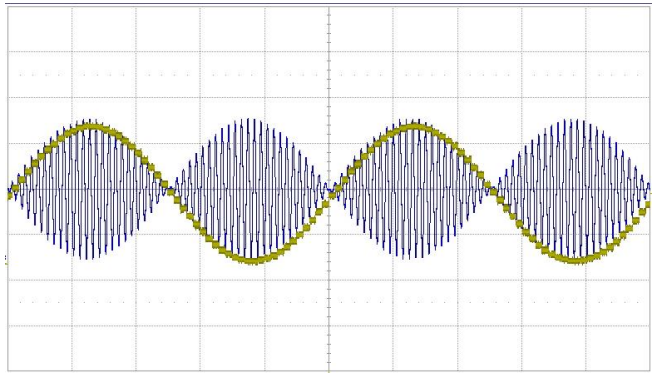
Phase-Locked Loop (PLL) method

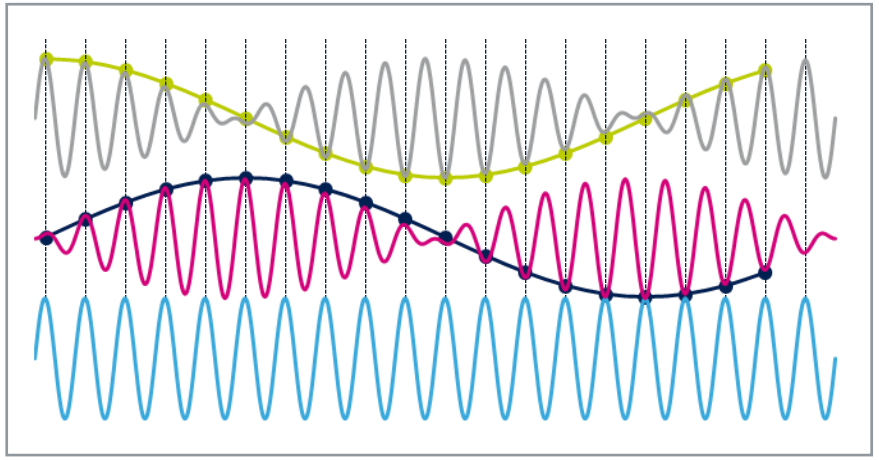
A closed-loop strategy, can accurately track the rotor position and rotor velocity simultaneously. The estimates of rotor position and velocity are continuously corrected by the tracking loop.

Implemented algorithm - ADC

Demodulation of sin and cos signals is performed sampling the two voltage inputs in their peak values (synchronized with the exciting signal).



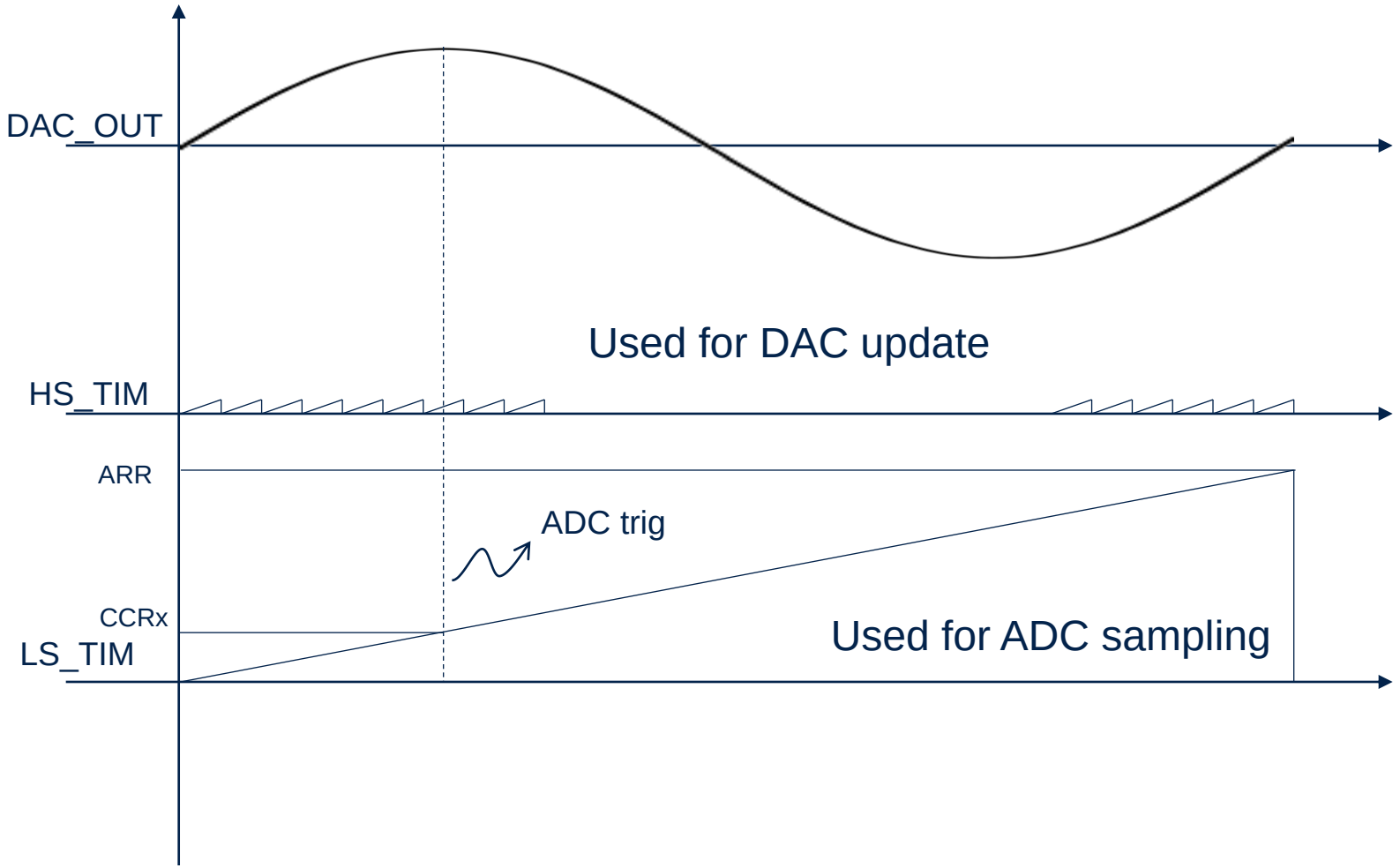




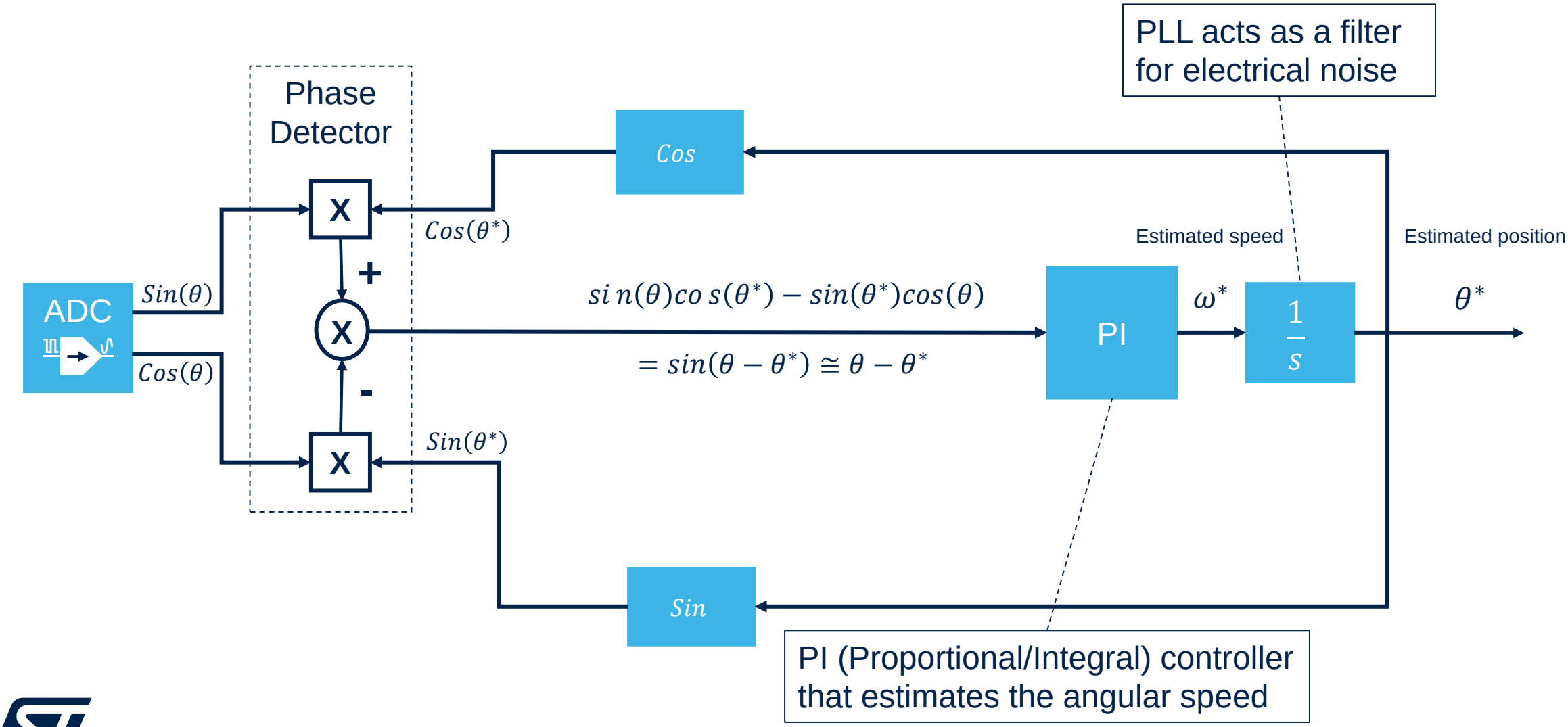
Reminder $\omega t = \theta$

Timers synchronization

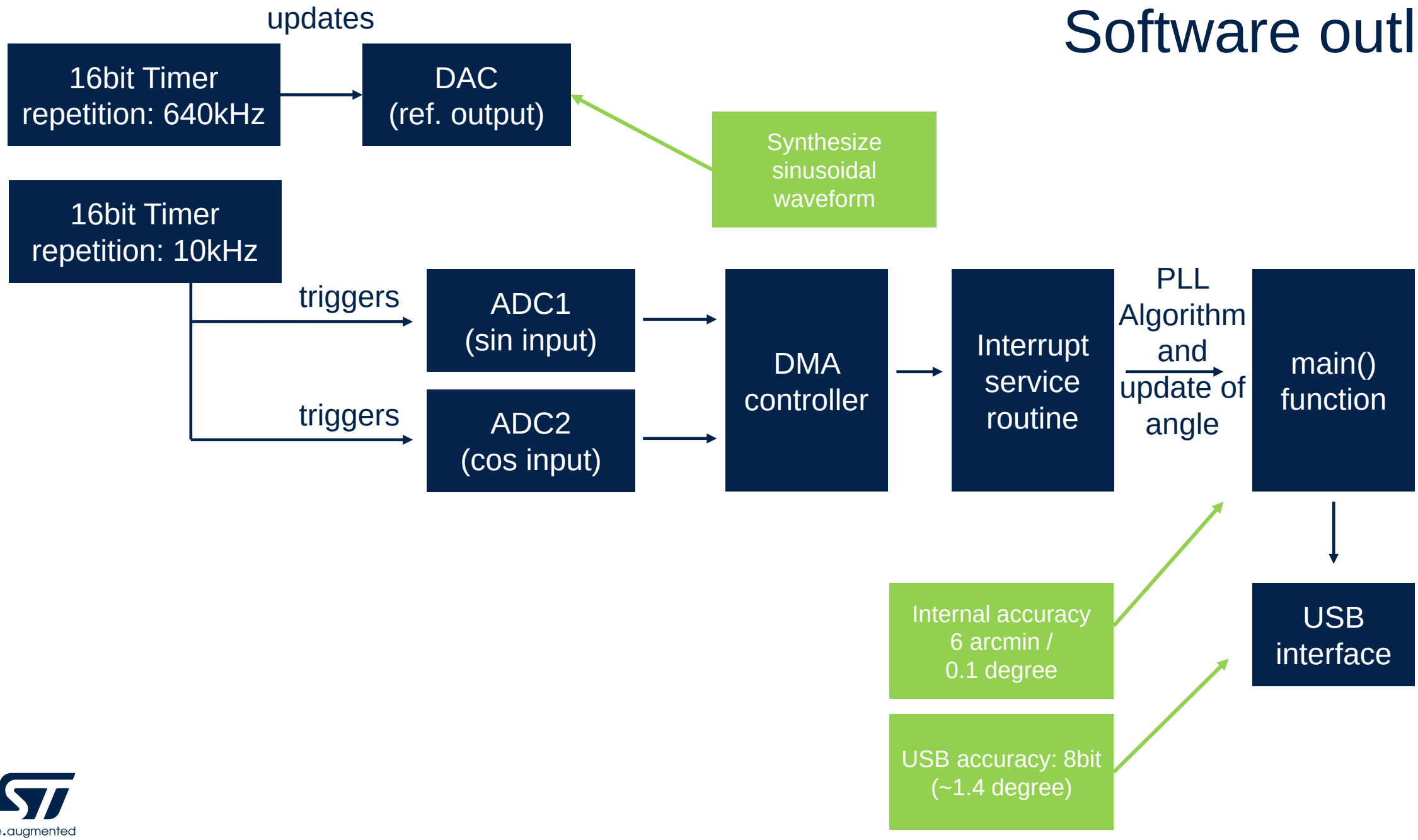
HS_TIM at 640kHz
64 steps to generate sine wave
Reference sine wave is at 10kHz



Implemented algorithm - PLL



Software outline



Application examples (1)

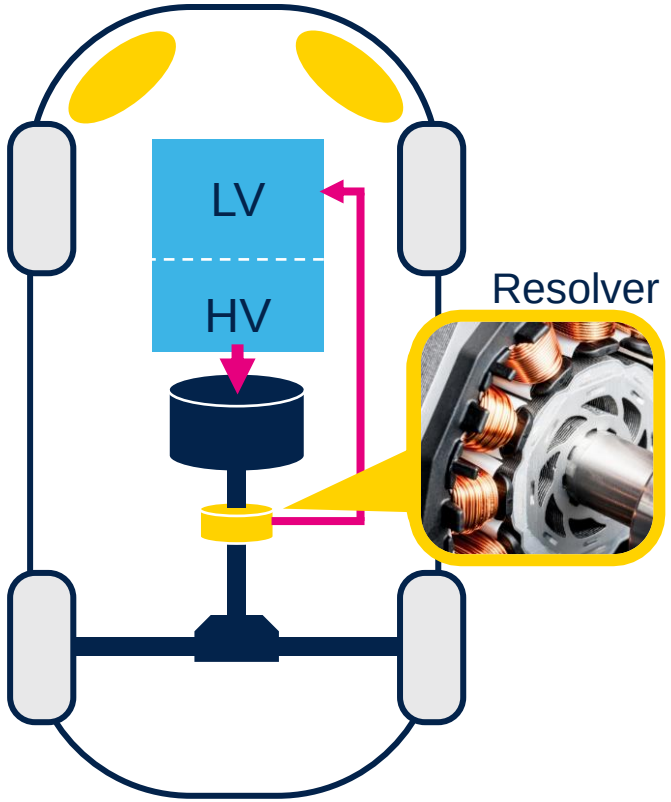
Automotive

- EV/HEV drive motor
  Detection of the magnetic pole position of the motor and accurate measurement of the rotational speed allows for efficient torque control of the motor under various driving conditions, enabling lower power consumption.

- Electric Power Steering
  Detection of the steering / wheel position and wheel rotation are needed for full autonomous driving as well as driver-assist features such as self-park and lane keeping, etc.

- Traction control
  Wheel speed (detected by a sensor installed on the rotational wheel axle) and motor torque are used to determine the maximum feedback gain for anti-slip control.

Block diagram



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Application examples (2)

Military

- Target acquisition systems
- Turret position
- Forward-Looking-Infra-Red (FLIR) systems
- Electro-optical systems
- Radar systems
- Missile seekers
- Motor commutation

Industrial

- Automation and process control
- Welding and painting robots
- CNC metal lathe
- Construction equipment

Aviation

- Position of flap on aircraft wing
- Throttle position
- Control stick position
- Actuator position

Demo introduction

- **DEMO:** Cart Racing on a rotary resolver enhanced steering wheel (steer-by-wire) powered by ST Op Amps
- **CP:** TSB582 (resolver driver)
  TSB514 (signal conditioning)
- **APPLICATION:** resolver driver (automotive/industrial)

SuperTuxKart racing game installed on a Windows PC

Plexiglass with Nucleo Board and ST Op Amps TSB582 + TSB514

Steering wheel equipped with a rotary resolver driven by ST Op Amps

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Demo signal chain

Open source video game:
SuperTuxKart

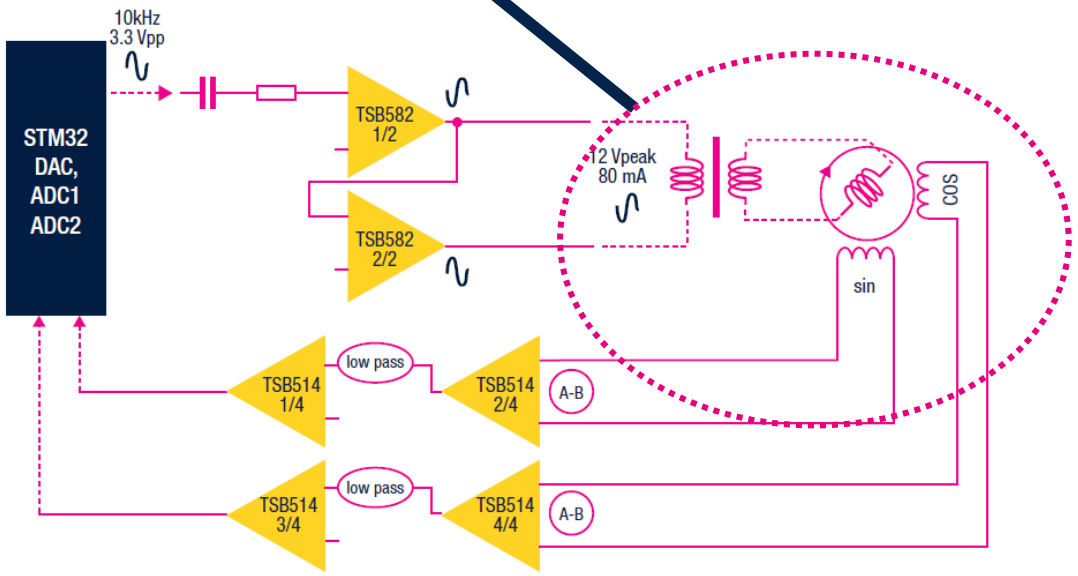
USB 2.0

Plexiglass with NUCLEO
+ STEVAL-TTM005V1

Resolver connector

Steering wheel joystick

Steering wheel allows only ~200° of rotation. If needed by the application, the number of revolutions must be tracked by another sensor.



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