Welcome to the webinar
“Torque measurement uncertainty 101”

The presentation will begin at **3 p.m. CET**

HBM: public

Organizational information

- All participants' **microphones** are **muted** during the webinar.
- Please do not forget to **activate** your PC **speakers** to enable **audio** or connect **headphones** to your PC.
- Please use the '**Questions and answers**' window, if you have any questions. We will answer questions at the end of the presentation.

- We will email **the presentation** to you after the webinar.
- The webinar is being **recorded** and will soon be made available on our website.

HBM: public

Speaker

- **Guy Beaho**
- HBM Business Development Manager with a focus on torque applications
- Graduate engineer & MBA

Guy Beaho

HBM Business Development Manager with a focus on torque applications

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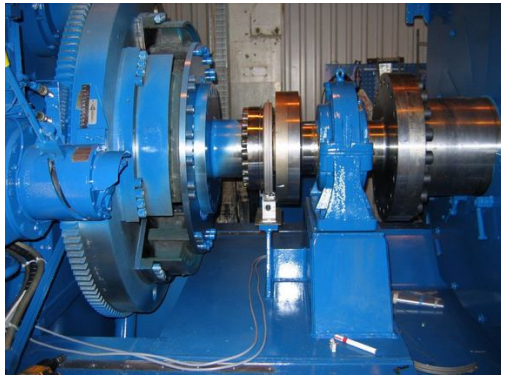
Torque Applications

Chemical: Viscosity Test mN.m → N.m

Offshore: Test & Monitoring of ship e#ngines > kN.m



Automotive: Performance Test N.m → kN.m

Energy: Test & Monitoring of elevetor drives kN.m → MN.m

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Agenda

1. Determination of applicable parameters & extension factors
2. Calculation of the single measurement uncertainty contributions
3. Calculation of the total measurement uncertainty
4. Calculation of the extended measurement uncertainty

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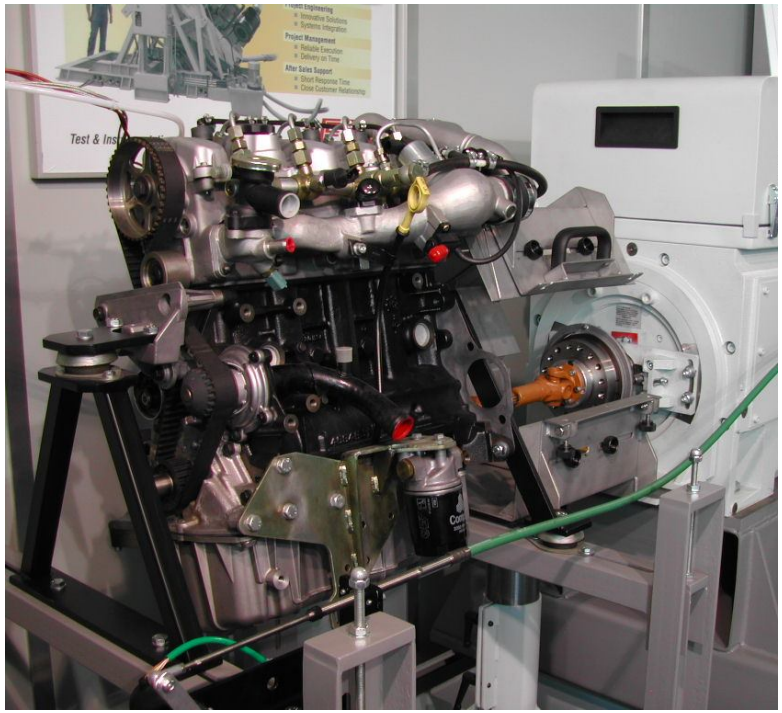
Application Sample



Torque range: -100 Nm … 700 Nm

Temperature range: 13°C … 43°C

Parasitic loads: $F_a \approx 0$

$F_l = 950$ N

$M_b = 95$ Nm

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Selection of the Transducer

smart torque® by HBM

T12

Digital Torque Transducer

Data Sheet

Special features

- Nominal (rated) torques of 500 N·m, 1 kN·m, 2 kN·m, 3 kN·m, 5 kN·m and 10 kN·m
- Nominal (rated) speeds from 10,000 rpm to 16,000 rpm
- Wide measurement frequency range up to 6 kHz (–3 dB)
- Fast digital transmission of measurement signals: 4,800 measured values/sec
- High resolution of 19 bit (integral method)
- Monitoring functions
- Extensive options

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Next Step

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Applicable Parameters & Extension Factors

			Distribution factors	
	parameter	related to	rectangle	normal
transducer	sensitivity tolerance [%]	max. torque	0,58	
	linearity + hysteresis [%]	full range	0,58	
	TK0 per 10K deviation from 23°C [%]	full range	0,58	
	TKC per 10K deviation from 23°C [%]	max. torque	0,58	
	repeatability [%]	Δ torque		1
design	total parasitic loads [%]	full range	0,58	
process	max. torque of the application [Nm]			
	max. temp. of the transducer [°C]			

$$\frac{1}{\sqrt{3}} = 0{,}58$$

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Calculation of the Single Measurement Uncertainty Contributions

A – Sensitivity Tolerance

Datasheet

Sensitivity tolerance (deviation of the actual output quantity at M_{nom} from the nominal (rated) sensitivity)		
Fieldbusses	%	± 0.05
Frequency output	%	± 0.05
Voltage output	%	± 0.1

$$u_{dC} = 0{,}58 \cdot d_C \cdot M_{\max} = 0{,}58 \cdot 0{,}05\% \cdot 700Nm = 0{,}20Nm$$

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Calculation of the Single Measurement Uncertainty Contributions

B – Linearity deviation & Hysterisis

Datenblattangaben

Linearity deviation including hysteresis, related to the nominal (rated) sensitivity		
Fieldbusses	%	± 0.02 (± 0.01 optional)
Frequency output 10 kHz/60 kHz	%	± 0.02 (± 0.01 optional)
Voltage output	%	± 0.05

$$u_{dlh} = 0{,}58 \cdot d_{lh} \cdot M_{nom} \cdot 2 = 0{,}58 \cdot 0{,}02\% \cdot 1kNm \cdot 2 = 0{,}23Nm$$

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Calculation of the Single Measurement Uncertainty Contributions

C_1 – Temperature effect on the zero signal(TK0)

Datasheet

Temperature influence per 10 K in the nominal (rated) temperature range		
on the zero signal, related to the nominal (rated) sensitivity		
Fieldbusses	%	~~± 0.02~~ (± 0.01 optional)
Frequency output	%	± 0.02 (± 0.01 optional)
Voltage output	%	± 0.1

$$u_{TK0} = 0{,}58 \cdot TK_0 \cdot M_{nom} \cdot \frac{\Delta T}{10K} = 0{,}58 \cdot 0{,}02\% \cdot 1kNm \cdot \frac{20K}{10K} = 0{,}23Nm$$

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Calculation of the Single Measurement Uncertainty Contributions

C_2 – Temperature effect on the sensitivity (TKC)

Datasheet

Temperature influence per 10 K in the nominal (rated) temperature range		
on the output signal, related to the actual value of signal span		
Fieldbusses	%	± 0.03
Frequency output	%	± 0.03
Voltage output	%	± 0.1

$$u_{TKC} = 0{,}58 \cdot TK_C \cdot M_{\max} \cdot \frac{\Delta T}{10K} = 0{,}58 \cdot 0{,}03\% \cdot 700Nm \cdot \frac{20K}{10K} = 0{,}24Nm$$

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Calculation of the Single Measurement Uncertainty Contributions
D - standard deviation of the repeatability

Datasheet

Rel. standard deviation of the repeatability, per DIN1319, related to variation of the output signal		
Fieldbusses/frequency output	%	± 0.01
Voltage output	%	± 0.03

$$u_{\sigma rel} = 1 \cdot \sigma_{rel} \cdot \Delta M = 1 \cdot 0{,}01\% \cdot 800\,Nm = 0{,}08\,Nm$$

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Calculation of the Single Measurement Uncertainty Contributions
E – Total Parasitic Loads

Axial limit force	kN	16	19	39
Lateral limit force	kN	4	5	9
Bending limit moment	N·m	200	220	560

Datasheet

7) Each type of irregular stress can only be permitted with its given static limit values (bending moment, lateral or axial load, exceeding the nominal (rated) torque) if none of the others can occur. Otherwise the limit values must be reduced. If for instance 30 % of the bending limit moment and also 30 % of the lateral limit force are present, only 40 % of the axial limit force are permitted, provided that the nominal (rated) torque is not exceeded. With the permitted bending moments, axial, and lateral limit forces, measuring errors of about 0.3 % of the nominal (rated) torque can occur.

	Limit load acc. to data sheet	Max. load acc. to application	Ratio max. load / limit load
Axial force	19 kN	≈ 0 N	0%
Lateral force	5 kN	0,95 kN	19%
Reaction or bending moment	220 Nm	95 Nm	43,18%
Total			62,18%

$$u_{para} = 0{,}58 \cdot d_{para} \cdot \frac{L_{para}}{L_{para,ref}} \cdot M_{nom} \cdot 0{,}30\% = 0{,}58 \cdot 62{,}18\% \cdot 1kNm \cdot 0{,}30\% = 1{,}08Nm$$

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Next Step

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3. **Calculation of the total measurement uncertainty**
4. Calculation of the extended measurement uncertainty

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Calculation of the total measurement uncertainty

$$u_{total} = \sqrt{u_{dC}^{\,2} + u_{dlh}^{\,2} + u_{TK0}^{\,2} + u_{TKC}^{\,2} + u_{\sigma rel}^{\,2} + u_{para}^{\,2}}$$

$$u_{total} = \sqrt{0{,}20Nm^2 + 0{,}23Nm^2 + 0{,}35Nm^2 + 0{,}24Nm^2 + 0{,}08Nm^2 + 1{,}08Nm^2}$$

$$u_{total} = 1{,}20Nm$$

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Extended Measurement Uncertainty

Confidence Interval [%]	Coverage factor k
68,27	1
90	1,645
95	1,96
95,45	2
99	2,576
99,73	3

$$U_{total} = k \cdot u_{total}$$

$$U_{total} = 2 \cdot 1{,}20\,Nm$$

$$U_{total} = 2{,}40\,Nm$$

Confidence Interval 95,45%

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Summary

1. Determination of applicable parameters & extension factors
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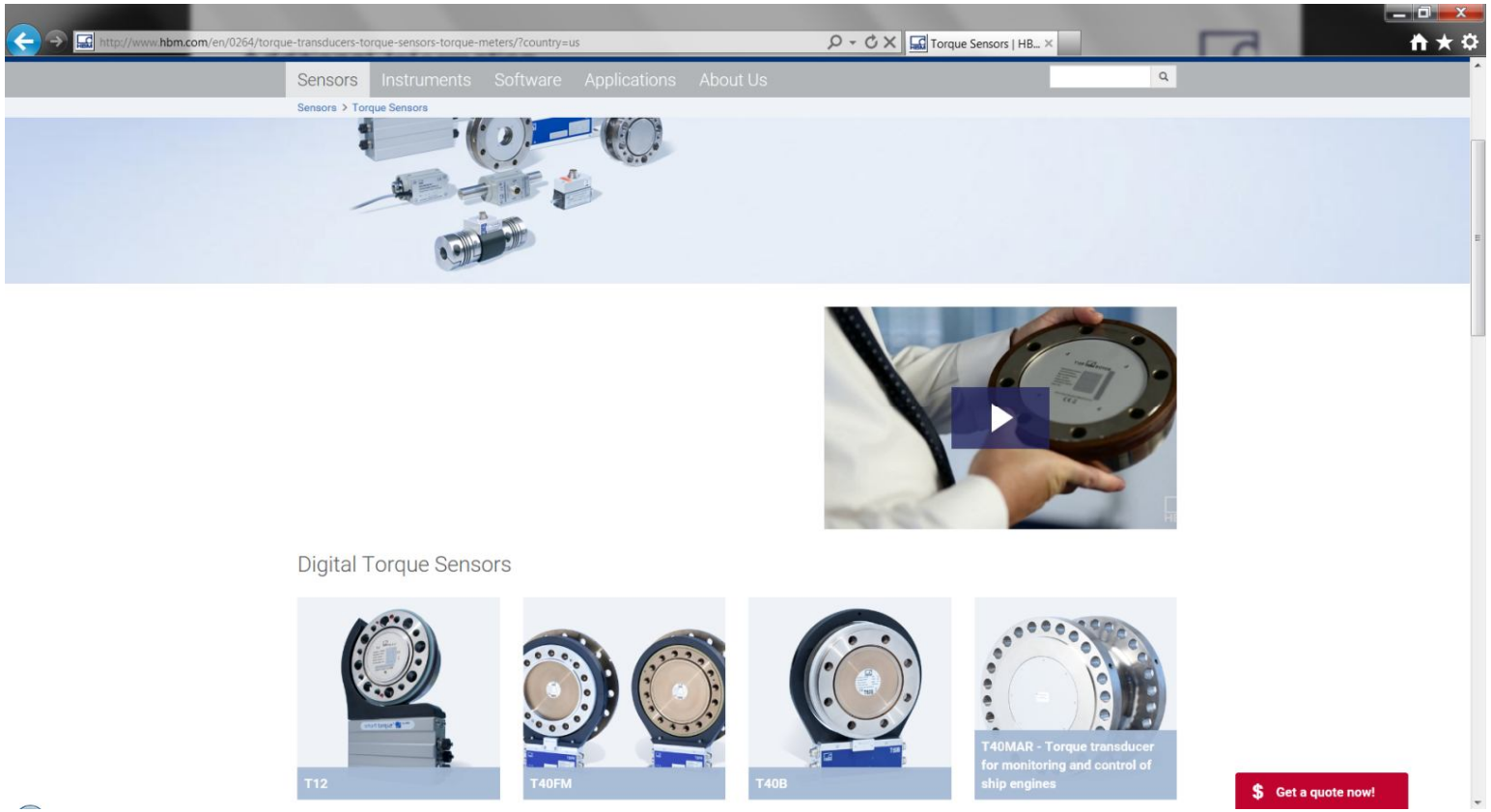
Additional Information

- http://www.hbm.com/en/0264/torque-transducers-torque-sensors-torque-meters/



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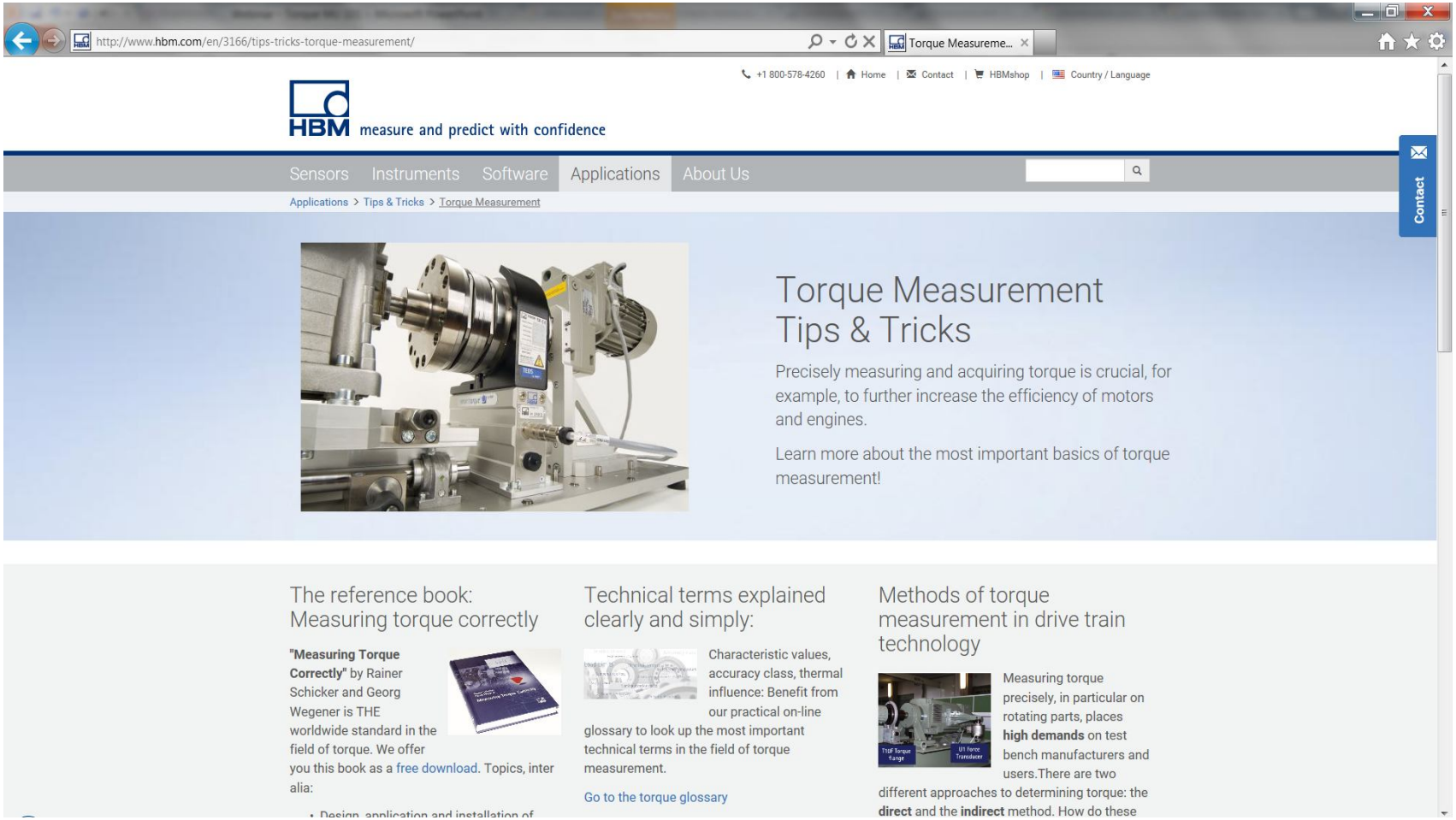
Additional Information

- http://www.hbm.com/en/3166/tips-tricks-torque-measurement/



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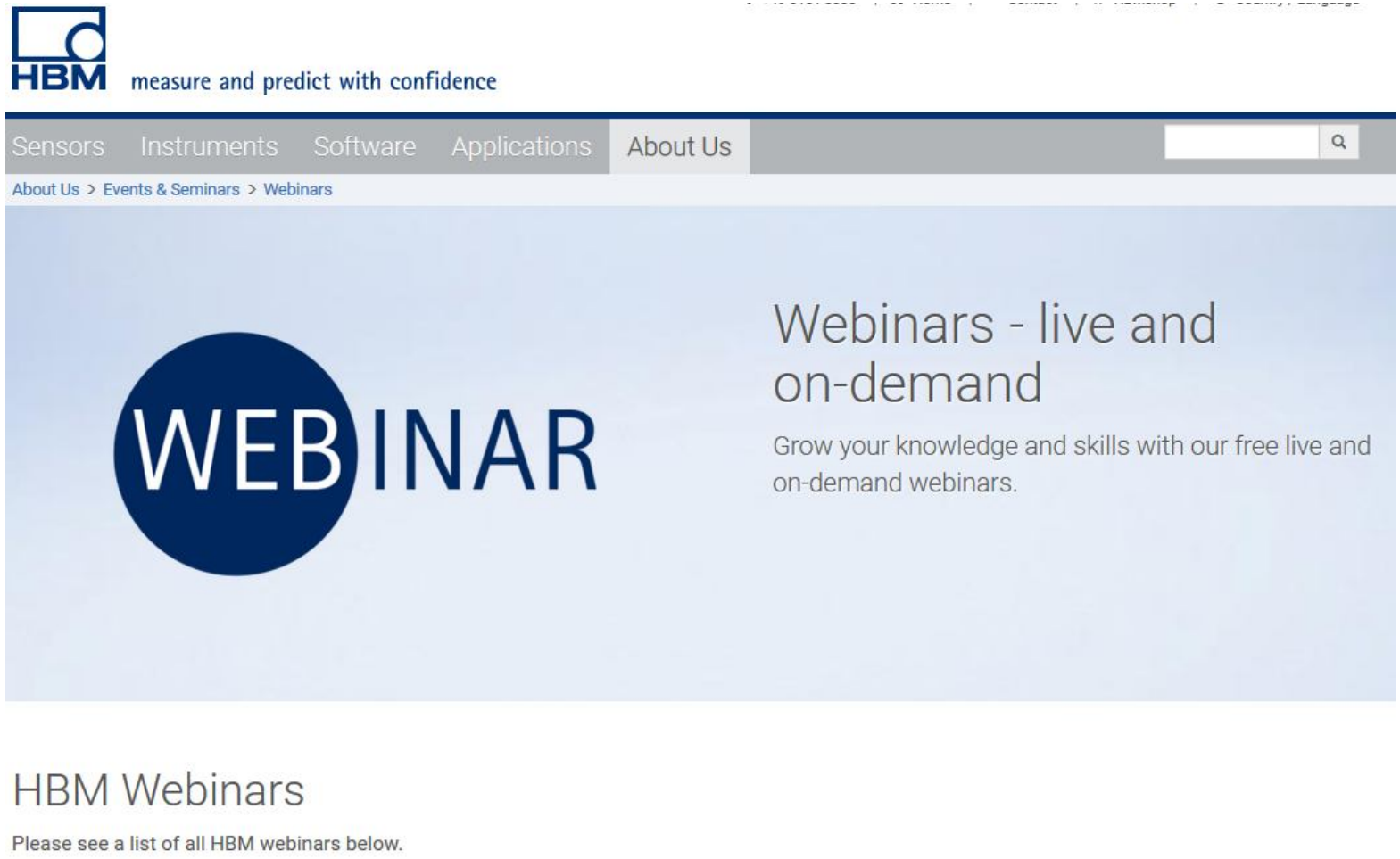
Additional Information

- http://www.hbm.com/en/3157/webinars/



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Questions & Answers

- Please contact us for further questions.
  We look forward to your email: emarketing@hbm.com

- Or email the speaker directly: guy.beaho@hbm.com

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