Tektronix[®]

Inverter Motor Drive Analysis

5 Series MSO Option 5-IMDA Application Datasheet



Get more visibility into your inverters, motors, and drive systems

Measurements and analysis on three-phase power systems are inherently more complex than on single-phase systems. Although oscilloscopes can capture voltage and current waveforms with high sample rates, further calculations are required to produce key power measurements from the data. Power converters based on Pulse Width Modulation (PWM), such as variable-frequency motor drives, further complicate measurements since filtering and triggering on PWM signals are challenging. Yet for most validation and troubleshooting, understandably their oscilloscope is the instrument of choice for designers. Special software, designed to automate power analysis on inverters, motors, and drives, greatly simplifies important three-phase power measurements on PWM systems and can help engineers get faster insights into their designs. The Inverter Motor Drive Analysis (IMDA) solution from Tektronix helps engineers design better and more efficient three-phase motor drive systems, taking full advantage of the advanced user interface, six or eight analog input channels, and 'High Res' mode (16 bits) on the 5 Series MSO. The IMDA solution provides fast, accurate, and repeatable results for electrical measurements on industrial motors and drive systems for AC induction motors, permanent magnet synchronous motors (PMSM) and brushless DC (BLDC) motors.

Key features and specifications

- Accurately analyze three-phase PWM signals used to drive AC induction, BLDC, and PMSM motors.
- Unique oscilloscope based phasor diagrams indicate V_{RMS}, I_{RMS}, and phase relationships at a glance for the configured wiring pairs.
- Debug motor drive designs by viewing the drive input/output voltage and current signals in the time domain simultaneously with the phasor diagram.
- Three-phase Autoset feature configures the oscilloscope for optimal horizontal, vertical, trigger, and acquisition parameters for acquiring three-phase signals.
- Measures harmonics per the IEEE-519 standard or using custom limits.
- Measures drive system efficiency using the 2V2I (two wattmeter) method.
- Quickly add and configure measurements through the intuitive drag and drop interface on the 5 Series MSO.

Measurement overview

Three-phase power converters such as variable frequency drives require a range of measurements during the design process. The Inverters, Motors, and Drives Analysis package for the 5 Series MSO automates key electrical measurements which are grouped into three categories:

- Input analysis
- Output analysis
- Ripple analysis

Each of these sections include key measurements which are critical to a motor design.

Input analysis

Input analysis includes the basic measurements used in most power equipment designs. The 5-IMDA solution automatically measures the current, voltage, and power values for different wiring configurations. The measurements can be set to measure 2V2I or 3V3I for 3P3W, and 3P4W to support various supply and motor configurations. Measurements can be performed line-to-line or line-to-neutral, to support delta or wye configurations.



Input analysis wiring configuration

Harmonics

Power waveforms are rarely textbook sinusoids. Harmonics measurements break down non-sinusoidal voltage or current waveforms into their sinusoidal components, indicating the frequency and amplitude for each component.

Harmonics analysis can be performed up the 200th harmonic. The maximum harmonic order can be set to suit your needs by specifying the range in the measurement configuration. THD-F, THD-R and fundamental values are measured for each phase. Measurements can be evaluated against the IEEE-519 standard, or custom limits. Test results can be recorded in a detailed report indicating pass/fail status.

IMDA MEAS 1	?	Measure	Search	Plot	More
HARMONICS	>	IMDA Mea	s 1º Harmor	nics'	·
CONFIGURE		INDATIAC	Phase 1	Phase2	Phase3
Wiring: 3 Phase-3 Wire (3V3I) Label Harmonice		F1 Mag(A): F3 Mag(A): THD-F(%): THD-R(%);	229.8 m 7.624 m 26.32 25.45	250.9 m 9.226 m 25.09 24.34	255.7 m 7.480 m 23.72 23.08
Voltage Source Current Source Edge Qualif Vab Ch 1 • Ia Ch 2 • Ch 1	ier T	V _{RMS} (V): I _{RMS} (A): TrPwr(W):	375.1 330.2 m 83.64	376.5 343.7 m 89.77	379.1 347.3 m 91.06
Vbc Ch 3 v lb Ch 4 v		Status: Freq: H _{COUNT} :	Pass	Pass 40.06 Hz 50.00	Pass
Vca Ch 5 v Ic Ch 6 v Cutoff					
Low Pass Filter Frequency(Fc)					
Line Frequency Auto					
Harmonics Range From manufacture and Tomana and To					
Standard					
IEEE 519-2014 None					
IEC 61000-3-2					
F Custom	>				
GATING Honzontal Ingge	>	Acquisi	tion		review

Compare harmonics measurements against industry standards or custom limits

Power quality

This group provides critical three-phase power measurements including: frequency and RMS magnitudes of voltage and current, crest factors of voltage and current, PWM frequency, true power, reactive power, apparent power, power factor, and phase angle for each phase.

Voltage and current vectors can be displayed on a phasor diagram so you can quickly judge phase shift for each phase and the balance among phases. Each vector is represented by an RMS value and phase is computed using the DFT method.

IMDA MEAS 1			?	IMDA Meas	1: Power C	Quality'	
					Phase1	Phase2	Phase3
POWER QUALITY			~	V _{RMS} (V):	375.1	376.5	379.1
CONFIGURE				I _{RMS} (A):	330.2 m	343.7 m	347.3 m
				I CF:	3.054	3.106	3.070
Wiring: 3 Phase-3 Wire (3V3	31)	Label	2.8 V	TrPwr(W):	83.26	88.53	90.39
		Power Quality		RePwr(VAR): AnPwr(VA):	-91.71 123.9	-94.35 129.4	-95.71 131.7
Voltage Source	Current Source	Edge Qualifier		PE:	980.8 m	991.3 m	974.4 m
Vab Ch 1	la Ch 2	T Ch 2	-	Freq:	4	0.07 Hz	
	CITE	Cir 2	_				
Vbc Ch 3 🔍	lb Ch 4	T	16 kV				
v Ch5	Ch 6	· · · · · · · · · · · · · · ·	4.8 V				
Vca chi s	IC CHO	and the strength of the second second					
Low Pass Filter	Cutoff Frequency(Ec)		-2.4 V				
1st Order -	1		 4.8 V				
Tst Order							
			840 V				
and the second second			220 V				
			5.2 V				
			2.5 1				
		42.2					
REFERENCE LEVELS		31.6					
GATING			>				

Easily configure the settings to get insight into the power quality

Output analysis

This group of measurements can help calculate the overall performance of the motor drive system.

Efficiency

Efficiency measures the ratio of the output power to input power for respective input and output V and I pairs. By using the 2V2I method, three-phase efficiency may be measured using eight oscilloscope channels (2V2I on the input side and 2V2I on the output side). The solution calculates efficiency at each phase and the total (average) efficiency of the system.

IMDA MEAS 1	\bigcirc	IMDA Meas	1: Efficiency'	
EFFICIENCY	>	VP:	Phase1 F 1 / + 0 681.6 W 6	Phase2 507.1 W
CONFIGURE		O/P: Eff:	509.9 W 5	540.2 W 38.98 %
Mining 2 Direct 2 Mine (2) (2)	Label	Total:	81.49 %	50.50 //
wiring: 3 Phase-3 wire (2V2I)	Label			
ab-cb ac-bc ba-ca	Efficiency			
Input				
voltage source Current source	Edge Quaimer			
Vac Ch 1 👻 la Ch 2 👻	Vac 🔻			
Vbc Ch 3 v lb Ch 4 v				
Cutoff				
Low Pass Filter Frequency(Fc)				
1st Order 🔹 1 kHz				
Output				
Voltage Source Current Source	Edge Qualifier			
Vxz Ch 5 💌 Ix Ch 6 💌	Vxz 🔻			
Wer Ch 7 x ly Ch 8 x	60 V			
vyz ch v ty cho				
Low Pass Filter Frequency(Fc)				
1st Order T 1 kHz				
YYYYYYYY				
REFERENCE LEVELS	,			
GATING	>			

Configure wiring and filters to perform efficiency measurements



Get complete insight into the overall system efficiency

Phasor diagram

The measurement displays the magnitude and phase angle between Voltage(V) and Current(I) vectors in a phasor plot. The V and I vectors depend on the wiring configuration.



Easily configure the voltage and current inputs to display phaser diagrams



Unique scope based phasor diagram feature provides the relation between the voltage and current vectors

Ripple analysis

Ripple is defined as the residual AC voltage on a constant DC component (offset). Typically, the ripple component is often small in magnitude relative to the DC component.

The solution measures two types of ripple:

- Line ripple
- Switching ripple

Line ripple: The line ripple measures the RMS at the configured line ripple frequency and the peak-to-peak value of the time domain waveform for the configured phases.

Switching ripple: The switching ripple measures the RMS at the configured switching ripple frequency and the peak to peak value of the time domain waveform for the configured phases.

IMDA MEAS 1	() IMDA N	leas 1: Line Phase1	Ripple' Phase2	Phase3
LINE RIPPLE		> RMS:	1 425.3 mV	383.0 mV	5 360.0 mV
CONFIGURE		Pk-Pk:	1.295 kV leas 2: Swite	1.307 kV thing Ripple	1.301 kV
Wiring: 3 Phase-3 Wire (3V3I)	Label		Phase1	Phase2	Phase3
	Line Ripple	RMS: Pk-Pk:	12.80 μA 2.012 A	16.65 μA 2.058 A	20.32 μA 2.080 A
Configuration					
Input Output					
Source					
ab Ch 1 💌					
bc Ch 3 💌					
ca Ch 5 💌					
Line Custom Frequency Frequency					
Custom 👻	50 Hz				
GATING		>			

Ripple analysis configuration can be set to look into line and switching ripple



Detailed ripple analysis being carried out on all three-phases

Report generation

The 5-IMDA software simplifies data collection, archiving, documentation of your design, and development process. It supports the report generation in MHT, PDF or CSV formats with pass/fail results for easy analysis.

Measurement Report Tel Atronix														
												Monday F	ebruary 3 2	020 10:54
etup Co	onfiguratio	n												
cope Detail	ls													
cope Mode	I Number		So	ope Serial Nu	mber		TekSo	ope Version			Scope Ca	alibration Stat	us	
ISO58			Q1	00118			1.24.6	5			Pass			
IDA Hig	h Level Co	onfigurati	on											
leasuremer	nt Type		Wi	ring	CO 2010		Conn	ection			L-L to L-I	4		
		Pan(a)		Mint	Mart	PL 251	field David	Resultation!	toour Man	A second Mile	A course Mary	Annual Die Die	Accum Std	Access De
lame	measurement	src(s)	Mean	Min ⁻	Max.	PK-PK	Sto Dev	Population	Accum Mean	Accum Min	Accum Max	Accum PK-PK	Dev	Accum Po
IMDA Meas 1 - Power Quality	VRMS	Phase 1 (Vab, Ia)	375.12 V	375.12 V	375.12 V	0.0000 V	0.0000 V	1	375.12 V	375.12 V	375.12 V	0.0000 V	0.0000 V	1
Juality		(Vab, Ia)												
luality	IRMS	(Vab, Ia)	330.21 mA	330.21 mA	330.21 mA	0.0000 A	0.0000 A	1	330.21 mA	330.21 mA	330.21 mA	0.0000 A	0.0000 A	1
luality	IRMS Voltage Crest Factor	(Vab, Ia)	330.21 mA 1.7386	330.21 mA 1.7386	330.21 mA 1.7386	0.0000 A 0.0000	0.0000 A 0.0000	1 1	330.21 mA 1.7386	330.21 mA 1.7386	330.21 mA 1.7386	0.0000 A 0.0000	0.0000 A 0.0000	1 1
Luality	IRMS Voltage Crest Factor Current Crest Factor	(Vab, Ia)	330.21 mA 1.7386 3.0543	330.21 mA 1.7386 3.0543	330.21 mA 1.7386 3.0543	A 0000.0 00000.0 00000.0	0.0000 A 0.0000 0.0000	1 1 1	330.21 mA 1.7386 3.0543	330.21 mA 1.7386 3.0543	330.21 mA 1.7386 3.0543	0.0000 A 0.0000 0.0000	0.0000 A 0.0000 0.0000	1 1 1
Juality	IRMS Voltage Crest Factor Current Crest Factor True Power Reactive Power	(Vab, Ia)	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	0.0000 A 0.0000 0.0000 0.0000 W 0.0000 VAR	0.0000 A 0.0000 0.0000 0.0000 W 0.0000 VAR	1 1 1 1 1	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR	0.0000 A 0.0000 0.0000 0.0000 W 0.0000 VAR	0.0000 A 0.0000 0.0000 0.0000 W 0.0000 VAR	1 1 1 1 1
uality	IRMS Voltage Crest Factor Current Crest Factor True Power Reactive Power Apparent Power	(Vab, Ia)	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA	1 1 1 1 1 1	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA	0.0000 A 0.0000 0.0000 0.0000 W 0.0000 VAR 0.0000 VA	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA	1 1 1 1 1
uality	IRMS Voltage Crest Factor Current Crest Factor True Power Power Power Power Factor	(Vab, Ia)	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA	1 1 1 1 1 1 1	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA	1 1 1 1 1 1 1
Juality	IRMS Voltage Crest Factor Current Crest Factor True Power Power Power Power Power Factor Phase Angle	(Vab, Ia)	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VA 0.0000 VA 0.0000 VA 0.0000 0.0000 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 UA 0.0000 0.0000	1 1 1 1 1 1 1	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 960.75 m -11.260 Degrees	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 VAR 0.0000 VAR 0.0000 VA 0.0000 0.0000 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 VAR 0.0000 VAR 0.0000 VA 0.0000 Degrees	1 1 1 1 1 1 1 1
Juality	IRMS Voltage Crest Factor Current Crest Factor True Power Power Power Power Power Pactor Phase Angle V Phase	(Vab, Ia)	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 14.260	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 11.260	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 11.260	0.0000 A 0.0000 0.0000 W 0.0000 VA 0.0000 VA 0.0000 VA 0.0000 Degrees 0.0000 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA 0.0000 Degrees 0.0000 Degrees	1 1 1 1 1 1 1 1 1 1	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 11.260	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 11.260	330.21 mA 1.7386 3.0543 83.258 W -91.713 VAR 123.87 VA 980.75 m -11.260 Degrees 0.0000 Degrees 51.260	0.0000 A 0.0000 0.0000 W 0.0000 VAR 0.0000 VA 0.0000 VA 0.0000 Degrees 0.0000 Degrees	0.0000 A 0.0000 0.0000 W 0.0000 VA 0.0000 VA 0.0000 VA 0.0000 Degrees 0.0000 Degrees	1 1 1 1 1 1 1 1 1

Views Time Domain



Global Configurat	tion					
Gating	Jitter Separation Model	Dual Dirac Model	Display Unit Type	Standard Reference Levels	Jitter Reference Levels	Lock RJ
None	SpectralOnly	PCIExpress	Seconds	Every Acquisition	First Acquisition	false
Reference Levels	Configuration					
Ref Levels			Ch1, Ch2	Ch3, Ch4, Ch5, Ch6		
Ref Level Type			Global			
Base Top Method			MinMax			
RiseHigh			90%			
RiseMid			50%			
RiseLow			10%			
FalHigh			90%			
FallMid			50%			
FallLow			10%			
Hysteresis			10%			

A sample IMDA test report file with summary, details, and corresponding images

Specifications

Wiring Configuration	3 Phase-3 Wire (2V2I), 3 Phase-3 Wire (3V3I), 3 Phase-4 Wire (3V3I)
L-L to L-N Conversion	Applicable for 3 Phase-3 Wire (3V3I) ¹
Input Analysis	Power Quality, Harmonics ² , Input Voltage, Input Current and Input Power
Ripple Analysis	Line ripple, Switching ripple
Output Analysis	Efficiency ³ , Phasor Diagram
Three-phase Autoset	For all measurements
Plots	Phasor diagram and harmonics bar graph ⁴
Report	MHT and PDF format, Data export to CSV format
Degauss/Deskew (static)	Automatic detection of probes, Auto Zero. User can deskew voltage and current probes, degauss the current probe from the menus for each channel
Source support	Live analog signals, reference waveforms, and math waveforms

⁴ Range filter as part of measurement configuration.

¹ For 3 Phase-4 Wire (3V3I) the connection is always Line to Neutral and for 3 Phase-3 Wire (2V2I), it is Line to Line.

² Supports Custom limits

³ For 2V2I wiring

Ordering information

Product	Options	Supported instruments	Bandwidth available
New instrument order option	5-IMDA	5 Series MSO (MSO56, MSO58)	• 350 MHz
Product upgrade option	SUP5-IMDA	5 Series MSO (MSO56, MSO58)	• 500 MHz
Floating license	SUP5-IMDA-FL	5 Series MSO (MSO56, MSO58)	• 1 GHz
			• 2 GHz

Recommended probes

Probe model	Description	Quantity
TCP0030A	Current Probes	3 for 3V3I wiring ⁵
THDP0200 or TMDP0200	High Voltage Differential Probes	3 for 3V3I wiring ⁵



Tektronix is registered to ISO 9001 and ISO 14001 by SRI Quality System Registrar.

Product(s) complies with IEEE Standard 488.1-1987, RS-232-C, and with Tektronix Standard Codes and Formats.



GPIB IEEE-488

Product Area Assessed: The planning, design/development and manufacture of electronic Test and Measurement instruments.

⁵ For performing efficiency measurement, four quantities are required.

Datasheet

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