Motor drives

motor type	classific.	feedbacks (superset)	PWM pattern	sensing methods	Primary objective	other objectives	implementation	dynamic response	modules /libraries	description /key words/significance of modules	simulation	applications
BLDC												
	sensored	hall effect	D-PWM-OFF----OFF-ON	hall effect	Speed or Torque control	Speed control	16 bit fixed point (IQ math)	medium	Closed loop speed control	maintain reference speed with load		fans, pumps,blowers, polishing tools, compressors,electric drive train
		encoder	D-PWM-OFF----!D-PWM-ON-OFF	encoder		Audible Noise reduction	32 bit fixed point (IQ math)		Closed loop current shaping	Noise, Torque ripple , efficiency,symmetry		general purpose motion
		current (through ADC)	D-PWM-!D-PWM----OFF -ON			efficiency	32 bit floating point		Phase advance	Operation beyond rated speed		
		DC bus voltage	D-PWM-!D-PWM----!D-PWM-D-PWM			DC Voltage variation			Accurate Speed estimation due to unequal sectors	precision, reduce torque ripple and speed oscillations		
		pot (reference)				Torque ripple control			Torque ripple reduction	smooth operation (needs a bit motor characterization)		
		digital reference keyed in				medium dynamic response			Cogging torque reduction	smooth operation		
						Filed weakening /(phase advance)			motor dissipated dynamic braking	smoothbraking		
						cogging torque handling for smooth operation			DC bus variation and ripple compensation	consistent operation over wide input voltage, input capacitor reduction		
									Noise reduction	reduced inductor kickback at commutation		
									4 quadrant operation	following a dynamic speed profile		
									Constant position sampled control algorithms	Optimal dynamic performance and estimation across speeds without memory consuming table lookups, Low speed operation without jerks		
									Encoder data processing	Clock mode or screw mode motor operation, Electrical and mechanical angle conversion IQ math		
									Duty limiting	Based on PWM switching pattern for protection		
									hall effect and encoder data spurious protection	Reliable operation of motor		
									hi speed reliable operation	7-8 PWM cycles per sector (~30Krpm etc)		
	sensorless	phase voltage	D-PWM-OFF----OFF-ON	comparator based backemf zerocross detection	Speed control	speed control	16 bit fixed point (IQ math)	slow	Closed loop speed control	maintain reference speed with load		fans, pumps,blowers, polishing tools, compressors
		DC bus current	D-PWM-OFF----!D-PWM-ON-OFF	3 resistor method of ST		Noise	32 bit fixed point (IQ math)		Startup	reliable startup of motor		
		pot	D-PWM-!D-PWM----OFF -ON	PWM triggered ADC based (majority detect based)		efficiency	32 bit floating point		Back emf signal filtering	reliable estimation of zero cross		
		DC bus voltage	D-PWM-!D-PWM----!D-PWM-D-PWM	multiple times per PWM triggered ADC		reliable zero cross detection			Zero cross detection estimation	estimation of zero cross accurately leads to symmetric operation, lower noise, lower speed and torque jitter, more efficient.		
		digital reference keyed in							Hi speed operation	7-8 PWM cycles per sector		
	sinewave	Hall effect	Complementary		Torque control	more Torque per amp		medium	Closed loop speed control	maintain reference speed with load		
		encoder			Speed control	Smoother operation			Closed loop current shaping	Noise, efficiency,symmetry		
		phase currents			Position control	Lower audible noise			Phase advance / field weakening	Operation beyond rated speed		
		DC bus voltage							DC bus variation and ripple compensation	consistent operation over wide input voltage, input capacitor reduction		
		leg currents							Noise reduction	reduced inductor kickback at commutation		
		pot							4 quadrant operation (external brake or regeneration)	following a dynamic speed profile		
		DC bus current							Constant position sampled control algorithms	Optimal dynamic performance and estimation across speeds without memory consuming table lookups		
									Encoder data processing	Clock mode or screw mode motor operation, Electrical and mechanical angle conversion IQ math		
									hall effect and encoder data spurious protection	Reliable operation of motor		
Brushed or universal												
		encoder	D-PWM-OFF----OFF-ON		Torque control	precision control	16 bit fixed point (IQ math)	fast	Closed loop position (servo)	precision control of instantaneous position (hi bandwidth ~ 50 hz)		servo control, machine tools, general purpose
		phase current	D-PWM-OFF----!D-PWM-ON-OFF		Speed control	trajectory following	32 bit fixed point (IQ math)		Closed loop velocity (servo)	precision control of instantaneous velocity (hi bandwidth ~ 200 hz)		
		resolver	D-PWM-!D-PWM----OFF -ON		Position control		32 bit floating point		Closed loop torque control	precision contol of toruq produced (hi bandwidth ~ 2000 Hz)		
		tachogenerator	D-PWM-!D-PWM----!D-PWM-D-PWM						Low speed operation	encoder data needs to be handled differently at low speed to improve smoothness (position synchronous algorithms)		
		position sensorless							Encoder data processing	Clock mode or screw mode motor operation, Electrical and mechanical angle conversion IQ math		
									trajectory generation (with settable max acceleration ,speed etc)	motion from point A to point B in a smooth and controlled manner		
									estimation of position/velocity without position feedback (gopinath observer)	Useful for speed estimation when position sensor is absent		
									kalman filter /Luenberger observer	Noise free precise position estimation		
									4 quadrant operation / dynamic braking and regenerative braking	fast / precision motor speed reduction and energy regeneration /dissipation		
									Deadtime compensation	Limit distortion due to deadtime and current crossing 0		
									Constant position sampled control algorithms	Optimal dynamic performance and estimation across speeds without memory consuming table lookups, Low speed operation without jerks		
									pid	digital PID for intuitive and analog inspired control		
									Direct digital implementation	Go to higher bandwidth for a given sampling frequency,		
ACIM/PMSM/IPM												
	common blocks											
									clarke	used for vector control		
									parke	used for vector control		
									Spave vector modulation	used for vector control (both in 2D polar and 3 phase voltage implementations)		
									sinewavePWM	used for vector control		
									inverse clark	used for vector control		
									Field weakening	to run motor beyond rated speed		
									Calculation of Id for optimal performance (low loss) in FW	lowest loss. (tricky in FW for IPM)		
									Calculation of Id for constant power (optimized for mips)	constant power .(implementation depends only on ref speed). Tricky for IPM.		
									saturation 2 D	proper voltage saturation for seamless FW full voltage utilization. (involves sqr root)		
	sensored Vector control	encoder	complementary /centrer aligned		Torque control	precision control	16 bit fixed point (IQ math)	fast	Closed loop position (servo)	precision control of instantaneous position (hi bandwidth ~ 50 hz)		servo control, machine tools, general purpose
		phase current (LEM , current sense IC)			Speed control	trajectory following	32 bit fixed point (IQ math)		Closed loop velocity (servo)	precision control of instantaneous velocity (hi bandwidth ~ 200 hz)		
		resolver			Position control	low noise	32 bit floating point		Closed loop torque control	precision contol of toruq produced (hi bandwidth ~ 2000 Hz)		
		tachogenerator				high power to weight ratio			Low speed operation	encoder data needs to be handled differently at low speed to improve smoothness (position synchronous algorithms)		
		position sensorless							Encoder data processing	Clock mode or screw mode motor operation, Electrical and mechanical angle conversion IQ math		
		DC bus voltage							trajectory generation (with settable max acceleration ,speed etc)	motion from point A to point B in a smooth and controlled manner		
									kalman filter /Luenberger observer	Noise free precise position estimation		
									4 quadrant operation / dynamic braking and regenerative braking	fast / precision motor speed reduction and energy regeneration /dissipation		
									Deadtime compensation	Limit distortion due to deadtime and current crossing 0		
									Constant position sampled control algorithms	Optimal dynamic performance and estimation across speeds without memory consuming table lookups, Low speed operation without jerks		
									pid	digital PID for intuitive and analog inspired control		
									Direct digital implementation	Go to higher bandwidth for a given sampling frequency,		
									Auto tuning	estimate parameters of motor and calculate the gains by itself		
	sensorless Vector control	phase current	complementary /centrer aligned		Speed control (internal torque control)		16 bit fixed point (IQ math)	slow	Closed loop velocity (servo)	control of avg velocity		fan blower compressor washing machine etc
		leg current (dual shunt)	centre point trigger				32 bit fixed point (IQ math)		Closed loop torque control	contol of torque produced		
		bus current (single shunt)	dual ADC trigger, fast opamp				32 bit floating point		Gopinath estimatior	estimate position (rotor angle) and speed precisely		
		DC bus voltage							PLL estimator	estimatot for ACIM and PMSM using PLL type. (not very good for FW)		
									frame dependent estimator for ACIM	etimator for rotor speed /slip frequency based on selection of rotating frame		
									Sliding mode observer	crude observer to estimate position (rotor angle) in PMSM		
									dead time sliding	used in single shunt implementation for accurate current measurement in low and high duty conditions		
									HF injection	Low speed and standstill position estimation (for sensorless FOC) by current injection in salient pole machines		
	scalar control	speed or slip frequency	complementary center aligned						reliable startup with a given current limit source	ACIM have a huge startup current with standard V/F control. With our		
		v/f drive										
		DC bus voltage										
stepper/ switched reluctance												
	default sensorless	phase currents	pulse		speed control	noise	16 bit fixed point (IQ math)	slow	microstepping	smoother operation at the cost of holding torque and get more positions in between		small scale miniature applications where position locking is important and adding encoder etc is not worth
					lock step position control	smooth operation	32 bit fixed point (IQ math)		closed loop current	allows higher speed and		
						jitter free operation	32 bit floating point					

Power electronics											
system type	**classification**	**Topology**	**feedbacks (superset)**	**Primary objective**	**other objectives**	**implementation**	**dynamic response**	**modules /libraries**	**description /key words/significance of modules**	**simulation**	**applications**
1 phase PFC / Bridgeless PFC/interleaved PFC											
	AC-DC	boost	input current	control input current waveshape	maintain DC bus output	16 bit fixed point (IQ math)	fast	sinewave table based from zero crossing	current shape follows fixed sinewave		white goods
			input voltage	(even at low loads etc)	load regulation	32 bit fixed point (IQ math)		sinewave reference table based on Vac	current shape follows fixed sinewave		
			output voltage		line regulation	32 bit floating point		Low load /DCM operation THD and PF limits to be met with frequency	meet regulatory limits at high line low load conditions		
								Variable frequency Pk and valley current control	THD at light loads and high line		
								Fixed frequency Pk current control	THD at light loads		
								dynamic trigger point selection	Low load and high load performance improvement		
								Load feed forward	bettter dynamic step response		
								Single cycle control digital implementation	simplicity of implementation		
								fault / overload protection schemes	customizable		
								Load sharing for interleaved converters	low bandwidth (low cost) current sensors (including Rdson of mosfet can be used to share currents)		
								soft start	soft start reduces stress and allows to cath bad init states		
3 phase PFC											
	AC-DC	H bridge	input phase currents	control input current waveshape	maintain DC bus output	16 bit fixed point (IQ math)	fast	vector control based	adapted from motor control, good dynamic response, will work evenf for high frequency AC ,unbalanced loads and bad waveform at input may be an issue		UPS systems /industrial and commercial app
			input phase voltages (Va,Vb,Vc) wrt virtual neutral	bi directional control (with high side MOSFETS)	load regulation	32 bit fixed point (IQ math)		sinewave control based	simple intuitive implementation. Need high badnwidth current feedback and controller		
			output voltage (Vdc)		line regulation	32 bit floating point		single cycle control	simplicity of implementation		
								SVM based	to allow Vdc to be low minimum value being Line to line inout voltage		
								soft start	soft start reduces stress and allows to cath bad init states		
DC DC converter											
	DC-DC	buck , push pull, full bridge , phase shift full bridge ,boost, buck boost, non linear topologies LLC resonant converters	output voltage	control output voltage	efficiency	16 bit fixed point (IQ math)		Control system design (phase margin /gain margin /digital PID/DDD)	important aspect for any control implementation		commercial ,server power supplies , intermediate power supplies, 12V, 48 V supplies etc
			input voltage		load regulation (stiffness)	32 bit fixed point (IQ math)		current mode control	gives better line regulation		
			inductor current		line regulation	32 bit floating point		peak current mode control	reduces SW and mips burden		
					reduce size of passive components			digital slope compensation	required for peak current mode control		
					fast dynamic response			voltage mode control	no current sensor required ,suffers from line regulation		
					phase margin			paralleling / (load sharing) single wire communication	redundancy , modular system etc		
					gain margin			load sharing with low bandwidth individual current sensors	low badwidth sensors only required. Save cost		
								synchronous rectification PWM pattern generation	improves efficiency by reducing diode conduction		
								DC bus compensation	possibility to reduce		
								Load current compensation	improves dynamic response , step load etc		
								current source	pushes a settable current in a voltage source /load etc.		battery chargers
								operating point model for non linear topologies such as LLC series resonant	get best dynamic performance		
DC-AC /UPS											
	DC-AC	UPS /offline /online	output voltage	output voltage should be sine wave	line regulation	16 bit fixed point (IQ math)		Sine wave generation with arbitrary phase ,frequency and amplitude	required in DC -AC systems		sinewave UPS
			sync voltage (bypass AC)		load regulation (stiffness with a given output capacitor)	32 bit fixed point (IQ math)		soft start	reduces load on system		
			inductor current		synchronization (phase and frequency)	32 bit floating point		overload -time protection . (110 % for 30 min etc)	limited time overloading. Cycle by cycle current limiting etc		
			load current		switching (related to synchro) between sources			Control system design to get best stiffness (load regulation , THD)	tricky part as the output capacitance is often limited which reduces default stiffness		
			switch current for protection					instantaneous sampled Current mode control	improves line regulation. Prevents flux walking of line transformers. Better dynamic response than RMS control		
			DC bus voltage					inout voltage feedforward	rejects DC bus ripple, varibale DC bus etc		
								Load current feedforward	10 X improvement in stiffness and improves waveshape with non linear loads such as rectifiers		
								Phase and frequency synchronization	allows output to be tied with another wavefrom with ptorgrammable slew rate		
								grid tieing	push current into the grid (offline and online)		
								paralleling schemes	N+1 redundancy by paralleling directly the sinewave output voltage		
								integration	Seamless integration of energy flow ,state machine ,control etc to realize complete system		
								deadtim control	handling deadtime to reduce distortion		
								feedforward controller	allows reference and ouput voltage to have minimum phase lag		
								Open loop control /RMS control	default better stiffness but slow repsonse		
								Control when voltage feedback is available only through a 50 Hz transformer	The transformer blocks out any DC component in output waveform. Hence it has to be handled mathematically. Refer slideshare.net/controltrix. It puts many caveats in the design of the control sytem with acceptable stifffness		
								cycle by cycle current limiting	instantaneous current limiting		

Other work	Features
Accurate temperature estimation of thermocouple output with high normal mode ripple rejection and CMRR	1 uV accuracy in 30 mV range resolution 1 in 72000 48 channels to sample and 2 channels for calibration etc long thermocouple cables pick up noise
Gimbal controller	stabilize camera in 2 degrees of freedom mounted on a moving platform (e.g.UAV) Use gyro and accelerometer feedback high accuracy high bandwidth controller to reject disturbances
estimation of radius of motion by accelerometer and gyroscope data	analytical estimation of radius noise removal kalman style filter
Kalman filter based improved 2D estimation of location by combining GPS and accelerometer data	improved location estimation GPS being choppy we can get accurate information in between
smart battery / battery management /smart charger	support multi chemistry / multi voltage battery systems Constant current mode /constant voltage mode trickle charging cell balancing pulse charging SOC estimation by impedance measurement dV/dt termination charge time measurement coulomb counting and voltage measurement model based observer for SOC temperature based termination calibration of SOC smart battery system where battery tells how much charging current is required, voltage required, state of charge, time remaining to charge etc SMBUS/CAN based