
Contents

1 HOW ARE ELECTRIC MOTORS USED?	1
1.1 How many motors are used in American and European homes?	1
1.2 Motors in domestic life	2
1.3 Electric motors in automobiles	4
1.4 Motors in information equipment	5
1.5 Motors on the factory floor and in robots	9
1.6 Automatic vending machines	11
1.7 Transportation	11
1.8 Motors in toys and amusement machines	11
1.9 Motors in vision and sound equipment	12
1.10 Motors in medical and healthcare equipment	13
1.11 Production growth of small motors	13
2 PHYSICAL PRINCIPLES OF VARIOUS TYPES OF MOTOR	15
2.1 Making a motor with a magnetic needle	15
2.2 Principles of a stepping motor without permanent magnet	18
2.3 Principles of a DC motor	21
2.4 Generator function in a motor	25
2.5 DC motor characteristics	26
2.6 Induction motors	31
2.7 The source of torque	35
2.8 Laboratory-made fluid motor using thermomagnetic effect	37
2.9 Shape-memory alloy motor	39
2.10 Electrostatic micromotors no wider than a human hair	39
2.11 Ceramic motors with minute movement	42
2.12 Ultrasonic-wave motors	43
2.13 Monorail ultrasonic-wave motors	48
2.14 Coils, inductors, and capacitors	49
3 ENGINEERING PRINCIPLES IN MOTOR DESIGN	51
3.1 Stator, rotor, and windings	51
3.2 AC motors: classification by rotor structure	55

3.3	Revolving magnetic field generation in the stator	71
3.4	What is a stepping motor?	74
3.5	DC motors	78
3.6	Universal motors	86
3.7	What is a brushless motor?	87
4	CLASSICAL MOTOR-CONTROL TECHNOLOGY	97
4.1	Dependence of AC motor speed on frequency	97
4.2	Classical method of changing speed with a single-phase AC motor	98
4.3	Variable-speed drive with controllable frequencies	99
4.4	Simple method of adjusting single-phase AC motor speed	100
4.5	Conventional DC motors regulated by voltage control	103
4.6	Speed control using a photo or magnetic encoder	107
4.7	Servoamplifier for a bidirectional DC motor drive	110
4.8	From voltage to current control	111
4.9	Controlling a stepping motor with pulse signals	112
4.10	Classical means of position control	114
5	POWER ELECTRONICS AND MODERN CONTROL METHODS	117
5.1	Power-electronic devices for motor control	117
5.2	Pulse-width control for saving energy	130
5.3	Pulse-width-modulated three-phase inverter	135
5.4	Servomotors	137
5.5	Servosystems using microprocessors	138
5.6	Fully digital control	140
5.7	Necessity for brushless servomotors	140
5.8	Vector control of induction motors	142
5.9	Smartpower integrated circuits for motor drive/control	142
5.10	Emerging new problems	143
6	SMALL MOTORS AND THE INFO-SOCIETY	144
6.1	Single-phase induction motors in automated factory machines	144
6.2	Low-cost mass-produced small DC motors	144
6.3	Coreless, moving-coil, and printed-circuit motors	146
6.4	Some small motors and the largest motor	148
6.5	Stepping motors with fine teeth	150
6.6	Brushless DC motors in information equipment	151
6.7	Linear motors	153
6.8	High-speed and direct-drive motors	157
6.9	The toroidal coil motor: an old motor in a new age	157

6.10 A brushless DC motor without permanent magnets	160
6.11 Frontiers in ultrasonic-wave motor technology	162
6.12 Analogy with biomechanisms	166
APPENDIX I. CLASSIFICATION OF MOTORS	169
APPENDIX II. HISTORY OF MOTOR SCIENCE	171
EPILOGUE	174
INDEX	xi