SYNCHRO AND RESOLVER CONVERSION

edited by

Geoffrey S Boyes
Product Marketing Manager

Copyright © 1980 Memory Devices Ltd

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, including photocopying, recording, and storage in a retrieval system, without the prior written permission of the copyright holder. Applications for permission should be addressed to the publisher.

International Standard Book Number 0-916550-06-0

Published by Memory Devices Ltd, Central Avenue, East Molesey, Surrey, KT8 0SN. United Kingdom. (Memory Devices Ltd is a division of Analog Devices Inc of Norwood, Mass. U.S.A.)

Phototypeset by Randall Typographic, 10 Barley Mow Passage, London W4 4PH.

Made and printed in Great Britain by
The Garden City Press Limited Letchworth, Hertfordshire SG6 1JS

Information furnished in this book is believed to be accurate and reliable. However, no responsibility is assumed by Memory Devices Ltd for its use.

Memory Devices Ltd makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights, nor do the descriptions contained herein imply the granting of licences to make, use, or sell equipment constructed in accordance therewith.

Specifications are subject to change without notice.

SYNCHRO AND RESOLVER CONVERSION

Dedication

This book is dedicated to the memory of Dennis McDonnell whose assistance during the book's preparation was invaluable.

Foreword

This all started with the invention of the wheel.....

Every industry is to some extent reliant on being able to measure angles, monitor rotation and control position, all of which involve transducing angular movement into electrical signals. Of the various transducers available for this purpose, the best, beyond question, are electromechanical synchros and resolvers. Industrial processes have over the past few years, become increasingly cost effective due to the availability of low cost digital computing, and consequently a need has arisen for converting the analog output of the synchro or resolver into digital information and vice versa. Our objective in writing this book has been to pass on to users information about synchro and resolver conversion which may be of assistance to them in making their engineering decisions.

In writing the book we have tried to strike a balance between the heavily theoretical and the need for a primer. Inevitably we run the risk of being accused of "talking up" or "talking down" to our readers. We have run this risk deliberately in order to embrace the widest possible readership. Hopefully the virtuoso reader can always start with the appendices!

We trust that you will find this book useful and consider that we have achieved our objectives. We will welcome the comments and suggestions of our readers for the benefit of future editions.

VAL O'DONOGHUE September 1980

	×			
				h.
		•		
		,		

Contents

CHAPTER ONE Synchros and resolvers	Pag 1
Introduction	1
What are synchros and resolvers?	
Synchros Synchros	1
Torque synchros	2
Control synchros	4
Resolvers	7
Feedback resolvers	10
Sweep resolvers	10
Variations on the synchro and resolver theme	10
Brushless synchros and resolvers	10
Electromagnetic type	10
Hairspring synchros and resolvers	10
Magslips Transolvers	11
Slab or pancake synchros and resolvers	12
Multipole or electrically geared synchros and resolvers	12 13
Inductosyns® and Rotary Inductosyns®	13
The Linear Inductosyn	14
The Rotary Inductosyn	16
Coarse/fine synchro and geared systems	17
Coarse-fine synchro torque chains	17
Coarse-fine synchro control chains	19
Synchro and resolver parameters	21
Reference voltages and frequencies	21
Part numbers	22
Impedances	23
Accuracy	23
Synchro and resolver reliability, environmental testing and military specifications	24
Reliability	24 24
Environmental testing and military specifications	25
Other angular transducers	28
Optical encoders	28
Absolute encoders	28
Multiturn optical encoders	30
Brush or contact encoders	30
Potentiometers	30
Rotary induction potentiometers or linear transformers	30
Comparison between synchros/resolvers and other angular transducers	30
Cost comparison	31
Resolution and accuracy Static and dynamic mechanical loading	31
Environmental considerations	31 31
Noise immunity	31

	Page
CHAPTER TWO Scott connected transformers, the representation of angles in digital form, logic inputs and outputs.	33
Introduction	33
Scott connected transformers	33
Synchro to resolver format Scott connected transformers	33
Resolver to synchro format Scott connected transformers The reflected resistance in the Scott connected output transformers	35
of Digital to Synchro converters The use of Scott connected transformers as the input to	35
Synchro to Digital converters Electronic Scott T transformers	36 37
The representation of angles in digital form	37
Binary coding	37
B.C.D. Binary coded decimal	38
Machine tool scaling (4000 counts) Military scales (6400 counts)	39 39
Degrees and Arc. Minutes	39
Logic inputs and outputs	39
Logic types Standard TTL	39 39
Low power Schottky TTL	40
Buffered Three-state	40
Interfacing TTL outputs with CMOS devices	40
Synchro and resolver connection conventions	41
Introduction	41
Synchro definitions Resolver definitions	41
Resolver definitions	42
CHAPTER THREE Synchro and resolver to digital conversion	43
Introduction	43
Function of SDC's and RDC's	43
Types of SDC and RDC	43
Tracking synchro and resolver to digital converters	45
Principles of the tracking converter	45
Comparison with a mechanical servo system Advantages of a tracking converter	47 47
Ratiometric operation	47
Noise immunity	48
Instant digital data	48
Velocity voltage outputs	48
Tracking converter packaging	48
Modules Hybrid converters	48
Connecting and using a tracking converter	49 49
Connecting the synchro or resolver inputs	50
Connecting the power supplies	51
Connecting the digital inputs and outputs	51
Data transfer	52
Direct output tracking converters Tracking converters with latched Three state outputs	52
Tracking converters with latched Three-state outputs Tracking converter terminology and definitions	54
Acceleration	55 55
Accuracy	56

CHAPTER THREE (continued)	Page
Bandwidth	57
BUSY output	57
Data output	57
Flicker	57
Harmonic distortion	57
INHIBIT	58
Jitter	58
Maximum data transfer time	58
Output digital word	58
Phase difference between signal and reference	59
Power supplies	59
Reference and signal Frequency	59
Reference Impedance	60
Reference voltage	60
Resistive scaling	60
Resolution	60
Signal impedance	60
Signal voltage	60
Speed voltages	63
Step response	63
Temperature range	65
Tracking rate	65
Transfer function	65
Velocity voltage output	65
Bandwidth and transfer function of tracking converters	65
Synchro to digital coarse/fine (Two speed) systems	66
Binary coarse/fine ratios	67
Non binary ratios	69
Calculating the resolution of the two speed output	09
for a given ratio	69
Accuracy and resolution in coarse/fine synchro and	137
resolver to digital systems	70
Coarse/fine converter systems	. U 71
Velocity voltage outputs from tracking converters	71
Introduction	71
Velocity voltages used in digitally controlled feedback loops	72
	74
Velocity feed forward in servo control Noise on tracking converter velocity output voltage	74
Linearity of the velocity voltage of a tracking converter	74
Emeanty of the velocity voltage of a tracking converter	F 5
Successive approximation synchro and resolver to digital converters	76
Introduction	76
Advantages of a successive approximation converter	77
Noise on the input signals	78
Important considerations when connecting the SSD1625,	78
SSD1626 and SSD1627	
CHAPTER FOUR Digital to synchro/resolver conversion	79
Introduction	79
Function of DSC's and DRC's	79
Principle of operation of DSC's and DRC's	79
DSC and DRC packaging	81
Transformation ratio or radius vector variation	81

CHAPTER FOUR (continued)	Page
Applying digital to synchro and resolver converters	83
Connecting the converter to the device to be driven	83
Considerations when connecting the power supplies	86
Variations of accuracy and performance with reference frequency	86
Loading the converters	87
Synchro control transformer loads	87
Resolver control transformer loads	90
Tuning synchro and resolver control transformer loads	90
Torque receiver loads	92
Control differential transmitters (CDX) as loads	95
Quadrature errors and reference phase shift	95
Reference phase shift	95
Quadrature errors	95
Digital to synchro two speed (coarse/fine) systems	98
Binary gear ratios	98
Non binary gear ratios	99
Driving loads greater than 1.3VA	100
CHAPTER FIVE Resolvers and Inductosyns in machine tool and robot control	101
Introduction	101
Inductosyn to digital conversion	101
Linear Inductosyns	101
Three speed Inductosyn systems	104
An alternative Inductosyn control system using an RSCT1621	104
The use of resolvers in linear measurement and control	105
Rack and pinion resolver drive	105
Static accuracy	106
Torque considerations	106
Lead screw resolver drive	107
Resolvers and converters for rack and pinion leadscrew	
axis measurement	107
Resolvers	107
Converters	108
The use of a solid state resolver control transformer in machine tool control	110
Resolver to digital converters in robot control	111
Controlling the velocity of linear displacements	112
Type 2 control loops	112
CHAPTER SIX Related conversion products	115
Introduction	115
Angle position indicator API 1620	115
Introduction	115
Applications of the API 1620	115
Visual display of angles from synchro or resolver format inputs	115
The use of the API for setting angles in binary form	116
The API 1620 used for checking loading errors in synchro systems	116
Use of the API for checking Scott connected transformers	117
Checking tuned systems using the API	118

CHAPTER SIX (continued)	Page
Applications of the digital vector generators DTM1716 and DTM1717	119
Introduction	119
Function of the Digital Vector Generators	119
DTM1716 and DTM1717 anti-glitch circuit	120
Applications of the Digital Vector Generators	121
High resolution stepping motor drive	121
Polar to cartesian transformation for X Y plotter inputs	122
Low frequency precision amplitude quadrature oscillator	122
Coordinate rotation by the use of sine/cosine multipliers	122
Digital angular shift of resolver form angular data	123
High resolution spectrum analysis	123
Very narrow band pass filtering	124
Use of the DTM1716 module in nuclear magnetic	
resonance testing of crystals	125
Applications of the synchro/resolver to D.C. converter type SAC1763	125
Introduction	125
Function	125
Relationship between input and output	125
Applications of the SAC1763	127
Recording of synchro or resolver information	127
Using the D.C. voltage output of the SAC1763 in a servo system	127
Using the SAC1763 in a servo where the input is analog	127
Solid state Dummy Director DDU1714	128
What is a "Dummy Director"?	128
Electromechanical Dummy Directors	129
Disadvantages of electromechanical Dummy Directors	129
The solid state Dummy Director	130
Applications of the solid state Dummy Director type DDU1714	132 132
Testing large naval servo systems	134
Checking the performance of a director	134
Testing naval retransmission units Checking the backlash in servo system gearboxes	134
Non-naval servo systems	136
Testing digitally controlled machines	136
resting digitally controlled machines	130
CHAPTER SEVEN Applications	139
Introduction	139
Applications	139
Synchronising the phase of high speed shafts	139
Precision control of the difference of speed between rotating shafts	140
Changing the speed of rotation of synchro or resolver format signals	142
Solid state synchro retransmission systems	144
Data transmission by synchro format signals	145
Laser theodolite angle measurement	146
The use of synchros or resolvers for positioning of reflectors	
in solar energy systems	147
Plan Position Indicator (PPI) waveform generation in radar systems	148
Plan Position Indicator (PPI) waveform generation in radar systems	
where only the geared up synchro information is available	149
Plan Position Indicator (PPI) waveform generation in radars from	
two speed synchro systems	149
Conversion of Azimuth Change Pulses (A.C.P's) in radar systems into	4
D.C. Sine and Cosine voltages for PPI displays	150

CHAPTER SEVEN (continued)	
Conversion of Azimuth Change Pulses (A.C.P's) in radar systems	
to synchro or resolver format	
Synchro or resolver to Binary Coded Decimal (B.C.D.) applications	151
True bearing to relative bearing conversion	152
Synchro and resolver to digital converters in avionic equipment	153
Plotting tables	154
Stitching machines	155
Bending machines	155
Wind direction and windspeed indicators	155
Fire control systems	156
Synchro or resolver to digital tangent conversion	157
Elbow linkage	159
Conversion of invariant Sine/Cosine DC voltages to synchro or resolver	
format signals	160
Relation between gimbal angles and the direction cosines	
in axis transformation	161
Interpolation of Moire fringe displacement measurements	161
interpolation of Mone tringe displacement measurements	101
APPENDIX A	167
Common synchro parameters	167
APPENDIX B	170
Synchro and resolver manufacturers	170
APPENDIX C	172
Harmonic distortion of the reference waveform	172
Common signal distortion	172
Differential distortion	173
APPENDIX D	175
Speed voltages in resolvers and synchros	175
Introduction	175
Speed voltages	175
Rejection of the speed voltages	176
The effect of phase shift between signal and reference	177
Reduction of signal to reference phase angle	178
Synthetic reference	178
APPENDIX E	180
Vector rotation algorithms	180
Variable size angular steps	183
An alternative algorithm	184
The solution to the Chebyshev difference equation	185
APPENDIX F	187
Effect of quadrature signals on servo systems	187
The effect of reference to signal phase shift with quadrature	190

xii