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Microcomputer Applications in Measurement Systems

C. J. Fraser

BSc, PhD, CEng, MIMechE, MInstPet
*Reader in Mechanical Engineering
Dundee Institute of Technology*

J. S. Milne

BSc, CEng, FIMechE
*Senior Lecturer in Mechanical Engineering
Dundee Institute of Technology*

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Preface

During the previous decade the most significant improvements in instrumentation and measurement have been centred round the development of microelectronic devices. The modern engineering laboratory displays an ever increasing range of microprocessor-based products: supplementing various instrumentation and primary sensors, and providing a new dimension of intelligence and control in engineering measurement systems. Information technology in the laboratory has removed the tedium associated with the data-taking process. Modern systems incorporating acquisition, logging, analysis and presentation of data are rapidly becoming the rule, as opposed to the exception. Microcomputers are therefore becoming increasingly evident in research and general experimental environments and undoubtedly they will continue to exert a growing influence in the enhancement of the basic instrumentation systems of the future. The importance of the application of microcomputers in experimentation has grown to the extent that an introductory text covering the fundamental principles would now seem to be particularly warranted.

To the uninitiated, a full understanding of the microcomputer-based experimental test facility would apparently demand a detailed knowledge of instrumentation, micro-electronics, high and low level computer programming, computer architecture, the experimental method and control engineering. With such an extensive range of sub-topics to be mastered, the task of familiarisation might seem daunting to all but the most determined. This however is not the case, since although a basic knowledge is certainly required in all of the above areas, all-round in-depth expertise is not. Against this backdrop, the scope of this text is to provide a foundation for the application of the new technology in the experimental environment. The text therefore covers all of the fundamental concepts within each of the sub-topics to a sufficient depth. This should enable the readers confidently to develop their own custom-built computerised data-acquisition and control systems and subsequently to use these systems to their

fullest advantage. Detailed expositions of the finer points are omitted, although the level which is covered will provide readers with a sound foundation upon which to develop their confidence in any of the specialist associated areas. An adequate number of references to the more specialist books are included as an aid to this development.

The book is intended primarily for students following a B Eng or a Higher National Diploma course in Engineering, but should prove useful to other science students who have a major element of experimentation incorporated in their courses. Research students about to develop an automated, or partially automated, experimental test facility may find the text of particular relevance. As an introductory text to a very broad based subject, the book should also prove useful to students following the new technology courses which are being introduced in a number of secondary school syllabuses.

Numerous full worked examples are included to lead the reader onto the more complex situations and gradually to instill confidence in the use of a microcomputer for the acquisition, reduction, analysis, storage and finally the presentation of experimental data. In addition, digital control strategies are included to give a balanced coverage of the utilisation of the microcomputer in the modern experimental test facility.

It is assumed that students will be studying concurrently, or have studied, a course in computer programming in some or other dialect of BASIC. Many of the examples and illustrative material are particular to the BBC microcomputer, with the 6502 microprocessor, or to the IBM-PC and compatibles with the 8088, or 8086, microprocessor. In this manner we hope to encompass as wide a range of microcomputer hardware, relevant to the needs of industry and educational establishments alike.

Wherever possible, the semi-conductor devices and various other integrated circuits are referred to in the text by their generic type numbers. For the added benefit of UK readers, the equivalent RS Components Ltd stock reference numbers are also quoted.

Most of the programs presented, with the exception of the very short ones, are actual machine listings of working code. In this way we hope to have minimised any errors in transcription of the code.

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We are also very fortunate to have had the very able services of messrs Ken Rusk and Bob Greig who have often transformed our scribbled and whimsical notions into quality hardware.

The support of Macmillan Education is gratefully acknowledged and particular thanks are also due to the reviewers, for their astute guidance in the preparation of the manuscript.

Lastly we would thank our wives, Ann and Isabel, for their unstinting faith that we would get it right eventually.

Dundee, 1989

C. J. Fraser
J. S. Milne

Notation

b	breadth (mm)
d	depth (mm)
e.m.f.	electro-motive force (volts)
f	frequency (Hz), also friction factor in pipe flow in chapter 2
f_c	cut-off frequency (Hz)
f_s	sampling frequency (Hz)
h	heat transfer coefficient ($\text{kW/m}^2 \text{ K}$), also manometer reading (mm)
i	current (amps)
k	thermal conductivity (kW/m K), also roughness height (mm)
k/D	relative roughness parameter in pipe flow (chapter 2)
$\dot{m}$	mass flow rate (kg/s)
n	integer number
p	pressure (kN/m^2 or bar)
r	resistance (ohms)
s	Laplacian operator ($\partial/\partial t$)
t	time (s), also temperature in degrees Centigrade
v	voltage (volts), also dependent variable in chapter 3
x	linear displacement (mm)
y	vertical displacement (mm)
A	cross-sectional area (m^2)
B	binary number
C	velocity (m/s), also used to denote a capacitor
C_d	discharge coefficient, drag coefficient
C_p	specific heat capacity (kJ/kg K)
D	diameter (mm)
E	error, efficiency, modulus of elasticity (N/m^2)
F	force (N)

G	gauge factor, Gray number, also used to denote a strain gauge
H	head (m)
I	current (amps)
K	calibration constant, gain
L	length (m)
M	arithmetic mean, mass (kg)
N	rotational speed (rev/min)
Nu	Nusselt number
O	observation, reading
P	dependent variable
Q	flow rate (litres/s)
R	resistance (ohms), also damping factor in chapter 8
R_0	resistance at zero degrees Centigrade
R_i	internal resistance (ohms)
Re	Reynolds number
S	spring stiffness (N/m)
T	torque (N m), also temperature in degrees Kelvin or Centigrade as specified in the text
T'	percentage turbulence
T_d	derivative time constant
T_i	integral time constant
U	mean velocity (m/s)
V	voltage (volts)
V_i	input voltage (volts)
V_o	output voltage (volts)
W	load (N)
X	numerical input
Y	numerical output
ΔR	change in resistance (ohms)
Δp	differential pressure (kN/m ²)
Δt	sampling interval (s)
Ω	ohms
β	resistivity (ohms/cm)
ϵ	strain
η	efficiency
μ	viscosity (kg/m s)
ν	Poisson's ratio
ξ	damping ratio
ρ	density (kg/m ³)
σ	standard deviation
τ	time constant (s)
ϕ	phase angle
ω	circular frequency (rad/s), also range of a variable in chapter 3

ω_c	cut-off frequency (rad/s)
ω_n	natural frequency (rad/s)
ω_d	damped frequency (rad/s)

Subscripts

o	referred to standard conditions, also used to denote output
i	input
ref	reference quantity
x	referred to a linear displacement
a	axial
t	transverse
T	total

Prefixes

k	kilo (10^3)
m	milli (10^{-3})
M	mega (10^6)
μ	micro (10^{-6})
n	nanno (10^{-9})
p	pico (10^{-12})