

# Publications in the First Twenty Years of Switching Theory and Logic Design

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## Abstract

*This paper reviews publications in switching theory and logic design up to 1958, including both mathematical foundations and engineering applications.*

## 1 Introduction

Switching theory is a theoretical basis for logic design which is a discipline in very foundations of computer sciences. However, it is closely related to signal processing and system theory.

If it is considered within the signal processing, switching theory is an area devoted to the processing of a particular class of signals, the logic signals, that are digital signals modelled by logic functions [4] including switching (SW) functions [21] and multiple-valued (MV) functions [15] as particular examples. Fig. 1 shows a classification of signals. Fig. 2 shows relationships among classes of logic functions used as models for digital signals. In this figure,  $G_i$  and  $R_i$  are finite discrete sets of the cardinality  $|G_i|$  and  $|R_i|$ , respectively.

If considered as a part of system theory, the logic design relates to the design of digital systems whose input and output signals can be described by logic functions. In electrical engineering, a system may be a computing device, a communication channel, an automatic control system, a computation procedure or the related program, and similar.

For mathematic descriptions of systems, some algebraic structure should be imposed to the domain and the range of input and output signals. A group is the weakest algebraic structure for the domain still providing a mathematically tractable model for a system [28]. For the range, it is usually assumed the structure of a field, that could be the field of rational numbers  $Q$ , complex number  $C$  or a finite (Galois) field  $GF(p)$ .

In particular, when switching functions are considered as functions on finite dyadic groups,  $C_2^n = (\{0, 1\}^n, \oplus)$ , where  $\oplus$  denotes modulo 2 addition, logic EXOR, then the logic networks relate to the dyadic systems [1], [2], [17]. Thus, logic networks are dyadic systems with the range of input and output signals restricted to the finite (Galois) field  $GF(2)$ . In the same setting, logic networks for MV functions are systems on  $p$ -adic groups into  $GF(p)$  [9]. A generalization to systems on different, not necessarily Abelian groups, is straightforward [5], [26]. Fig. 3 shows the relationships among systems on groups.

## 2 Background and History of Switching Theory and Logic Design

Applications of switching theory in engineering practice, which means the development of switching theory and logic design, dates back to the introduction of transmission, storage, and processing of information in digital form [8], [23]. It is believed by many authors that switching theory as a separate discipline originates in 1938 due to the publications by Shannon [24], Nakashima [16], and Shestakov [25]. However, its mathematics foundations are set quite earlier in mathematical logic and related areas.

Fig. 4 express the relationships of switching theory and logic design to signal processing and system theory.

The origins of these disciplines, the switching theory and logic design as the realizations of it, can be traced in both these directions, towards signal processing and system theory. In particular, it is apparent that their development in the Western European countries and USA were primarily related to the signal processing within attempts to solve some problems as, for example, those

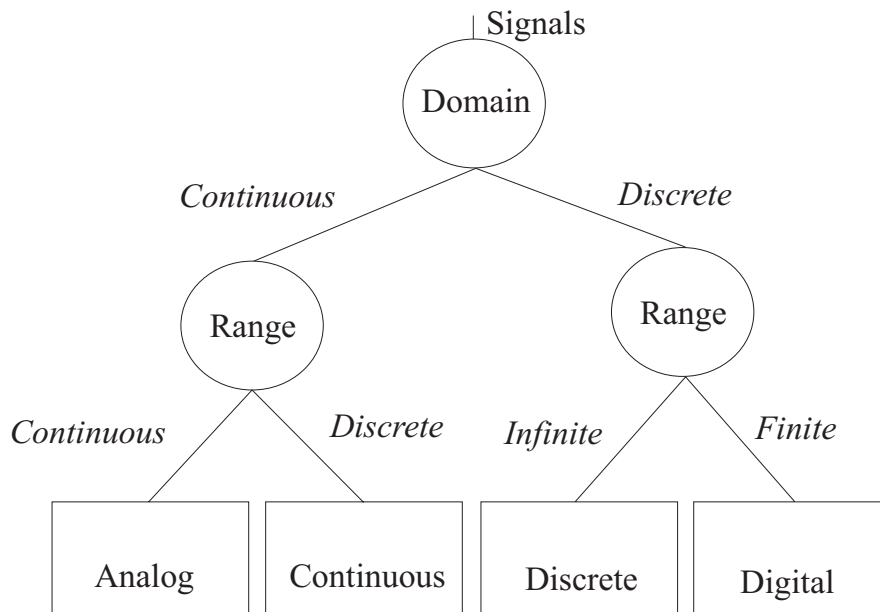


Figure 1: Signals.

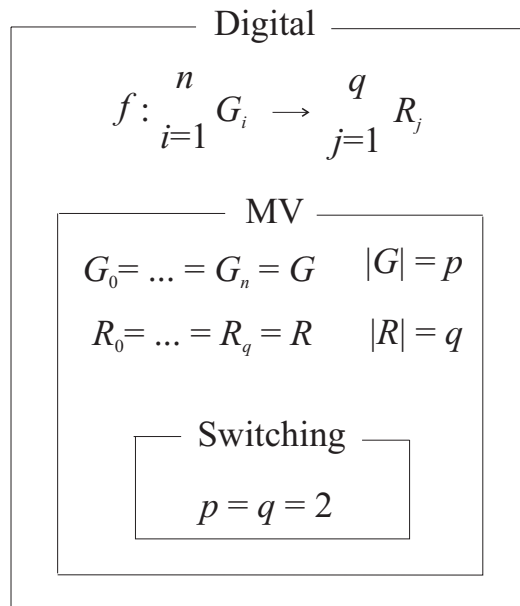


Figure 2: Logic signals.

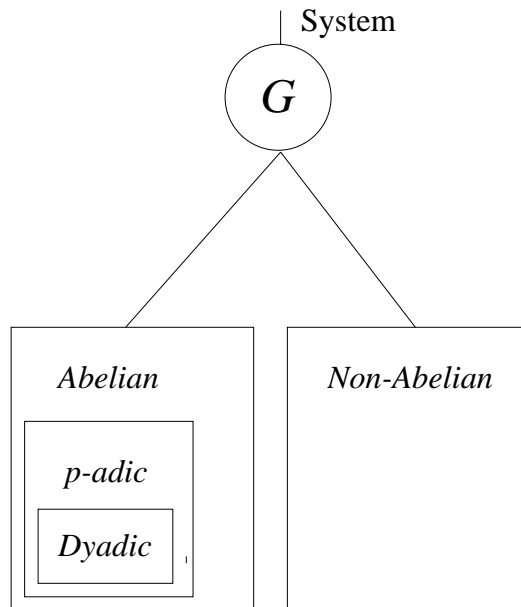


Figure 3: Classification of systems on groups.

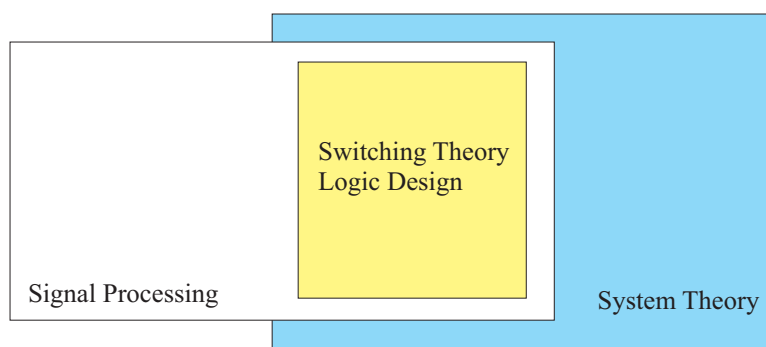


Figure 4: Switching theory and logic design.

arising in switching in railroad systems, information transmission and error correction, and automatic telephony. However, in the East European countries and former Soviet Union, the development of switching theory and logic design originates in system theory related primarily to automatic control problems.

In Japan, the development of these areas started with interest in the design of relay network systems [16]. However, the approaches related to the system theory were also used. In particular, the group theoretic approach to logic design originated in the work by Komamiya [7].

### 3 Contents and Presentations

This publication presents a compilation of references in the area of switching theory and logic design until 1958 ordered by the year of publication with authors in the alphabetical order within. The main sources of information were [3], [6], annual bibliographies by [11], [12], [13], [14], [18], [19], [20], and Addendum A.7 in [21]. Besides a study and comparison of these publications, a considerable number of references were provided through a communication and correspondence with researches in this area. In that respect, the authors are very grateful to Prof. Vladimir D. Malyugin of Institute of Automatic Control, Moscow. A number of references is due to our own search intended primarily to establish the links of former results to some topics of present research interests.

### 4 Closing Remarks

Besides rather straightforward applications of ancient theory and old methods, when that is possible, under a proper interpretation and after possible suitable reformulations, to different data structures [27], and new technologies [22], the reconsideration of former work in an area can be useful as a source of new ideas [10]. We believe that this publication may contribute to these attempts.

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