Politechnika Łódzka
Instytut Elektroniki

Programowanie Mikrokontrolerów

Magistrala 1-Wire

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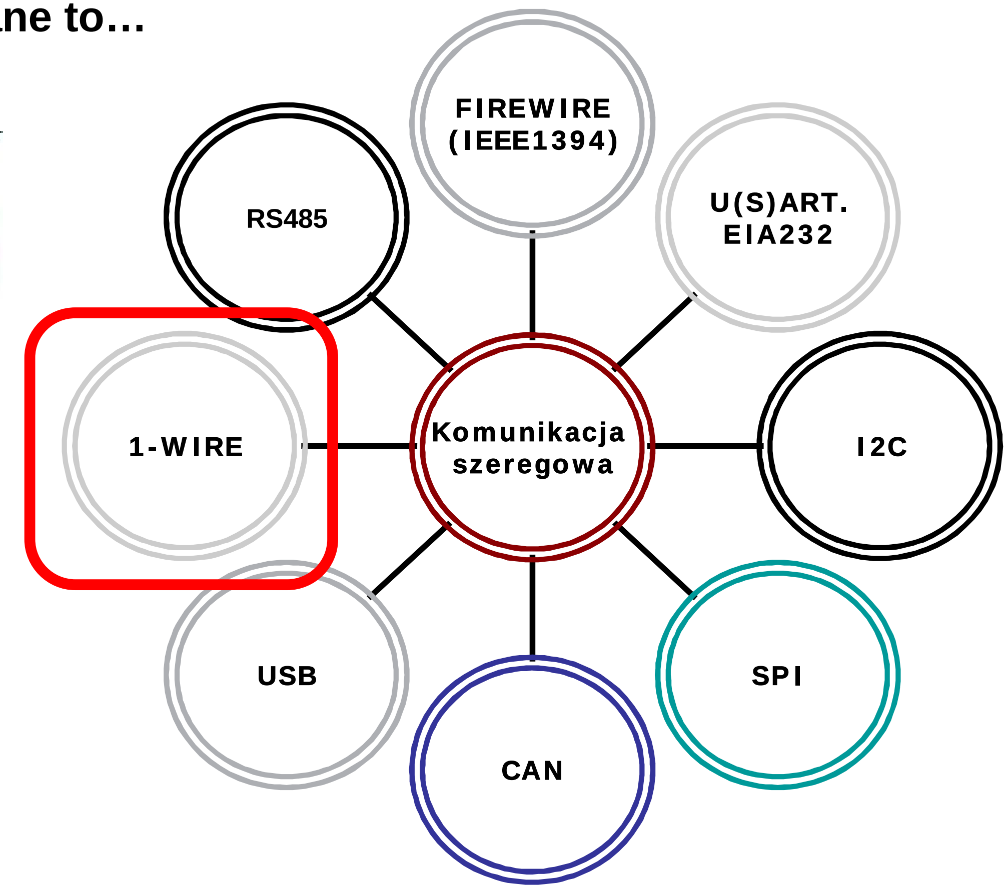
Zakład Elektroniki Medycznej

Komunikacja szeregowa

- Jakie znamy typy komunikacji szeregowej?

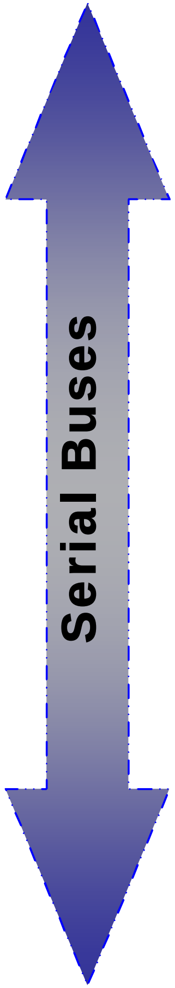
Prawdopodobnie najbardziej znane to…



Zagadnienia

- Wprowadzenie
- Dostępne układy
- Przykłady zastosowań
- Komunikacja w standardzie 1-Wire
  - *Time Slots*
  - Kolejne fazy procesu komunikacji
  - Komendy
  - Przeszukiwanie magistrali
  - Wymiana danych
  - Zasilanie układów z magistrali
- Komunikacja 1-Wire na przykładzie układu DS18B20
- Dodatkowe informacje

1-Wire



1-Wire and iButton

iButton®

- 1-Wire:
  - Szeregowa, dwukierunkowa, half-duplex, zawsze nadzorowana przez układ *Master*,
  - Jedno urządzenie *Master* (możliwy *multidrop*) kontroluje kilka urządzeń *Slave* podłączonych do magistrali,
  - Pozwala na zastosowanie tylko jednego przewodu do transmisji danych i zasilania urządzenia oraz przewodu odniesienia (GDN) (możliwość zasilania układów podrzędnych z magistrali),
  - Dwie prędkości komunikacji:
    - Standard: 15,4 kbps
    - Overdrive: 125 kbps
  - Urządzenia SLAVE adresowane fabrycznym, 64-bitowym identyfikatorem – unikalnym dla każdego z nich.

źródło: www.maxim-ic.com

1-Wire

Serial Buses

1-Wire and iButton

iButton®

- 1-Wire:
  - Standard rozwinięty przez firmę Maxim/Dallas Semiconductors,
  - Bardzo niewielki koszt implementacji (jedno GPIO – *open-drain*, najczęściej emulowana przez software lub implementowana z użyciem bloków UART),
  - Stosunkowo niskie prędkości transmisji,
  - Zazwyczaj stosowana do komunikacji z sensorami (termometry, czujniki wilgotności), pastylkami identyfikacyjnymi iButton, układami RTC oraz układami pamięci.

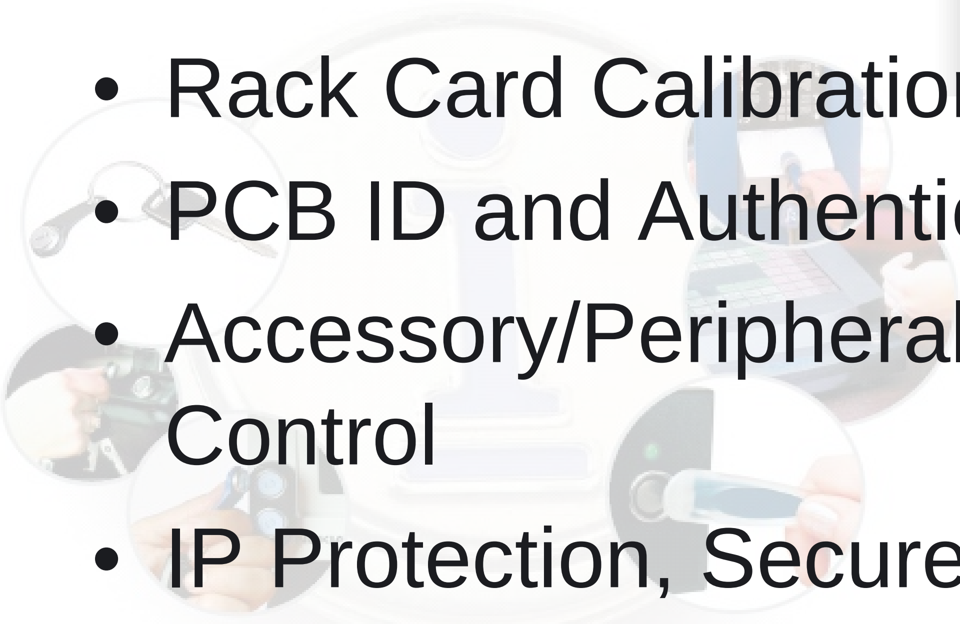
źródło: www.maxim-ic.com

Dostępne produkty

- 1-WIRE Products, m.in.:
  - Pamięci: EPROM, EEPROM, ROM
  - Sensory temperatury, termostaty,
  - Przetworniki ADC,
  - Układy RTC,
  - Układy nadzoru baterii,
- iButton, m.in.:
  - Pamięci: EPROM, EEPROM, ROM (również szyfrowane),
  - Sensory temperatury, wilgotności,
  - Układy RTC,

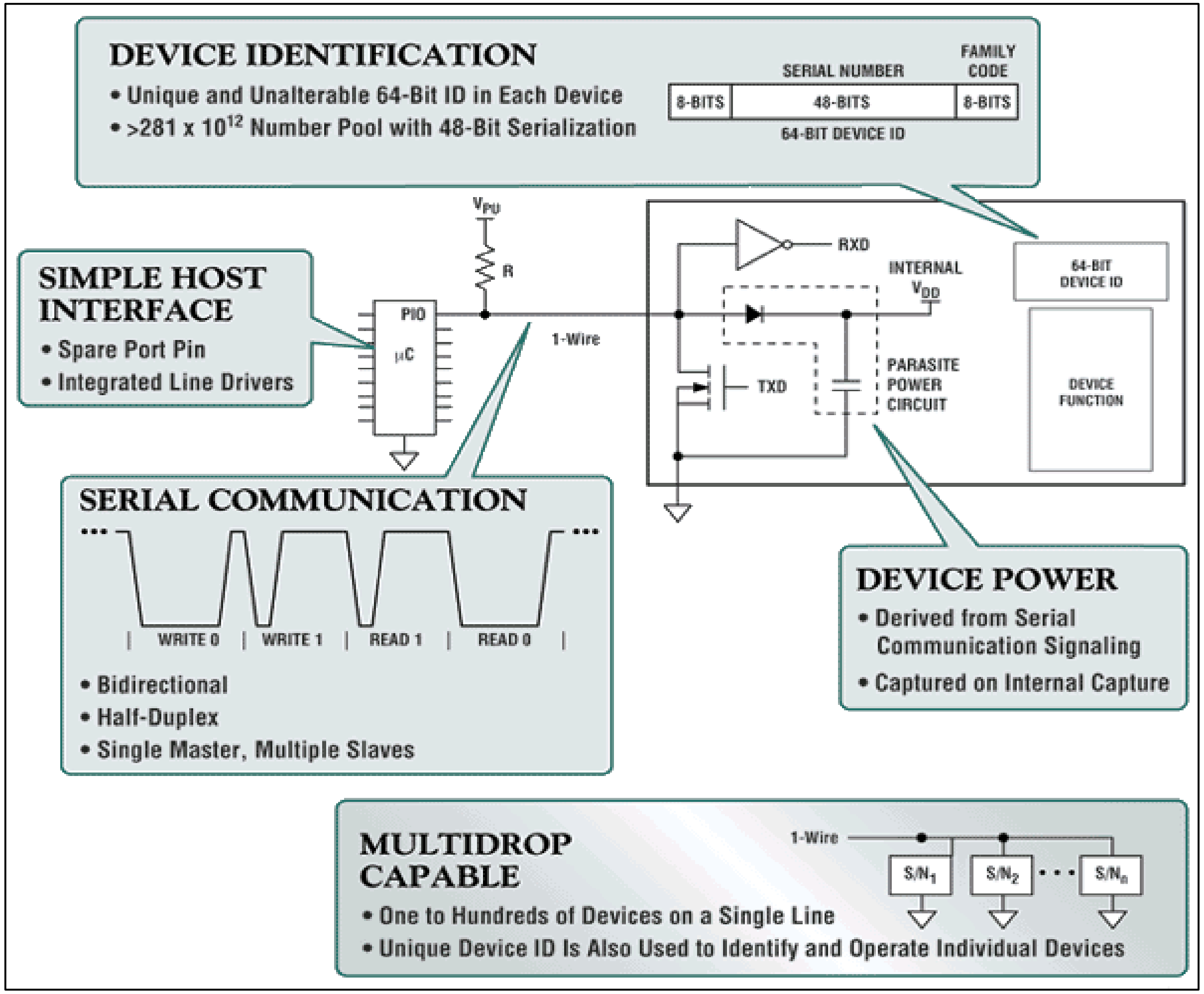
Przykłady zastosowań

- Print Cartridge ID
- Medical Consumable ID
- Rack Card Calibration and Control
- PCB ID and Authentication
- Accessory/Peripheral Identification and Control
- IP Protection, Secure Feature Control, Clone Prevention



Building Access | *Key Control Systems*
Biometric Data Carriers | *Standalone Locks*
Computer/Network Security | *POS Terminal Access*
eCash Systems | *Time and Attendance Systems*

Komunikacja w standardzie 1-Wire

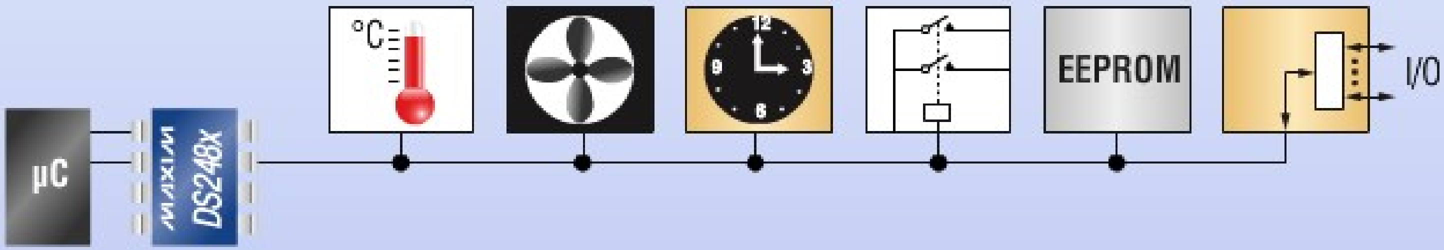


źródło: www.maxim-ic.com

Wprowadzenie do komunikacji

1-Wire Introduction

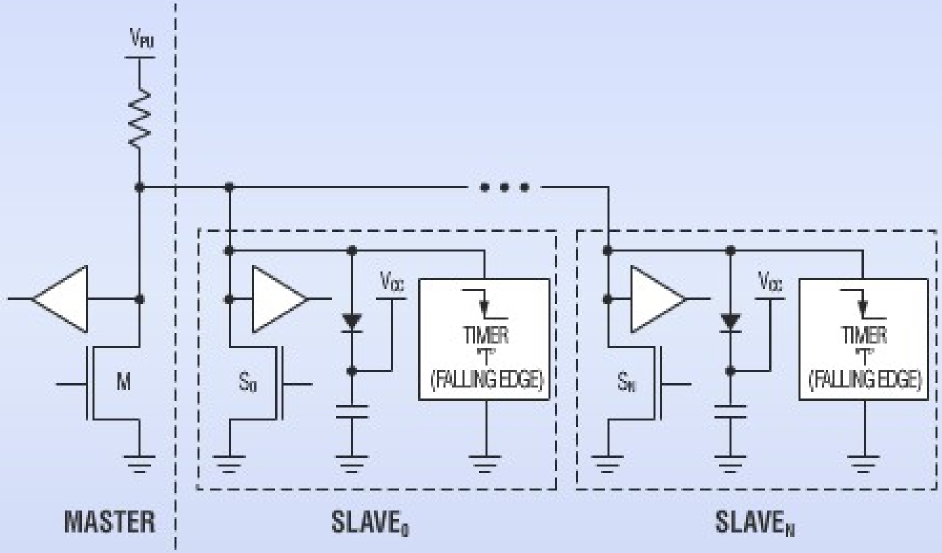
- Bidirectional, Half-Duplex, Serial Signaling Protocol that Powers and Operates Devices over a Single Connection and Ground Return
- Single Master Connected to One or More Slaves; Multidrop Capable
- Two Serial Communication Speeds
  - Standard: 15.4kbps
  - Overdrive: 125kbps
- Factory-Programmed, Unique Unalterable ID in Every Device
- Add Control, Memory, and Mixed-Signal Functions with a Single Contact



Wprowadzenie do komunikacji

1-Wire Introduction

- Master Initiated and Controlled Communication
- Low-Cost Master Configuration
  - Open-Drain Master
  - 3V to 5V Resistive Pullup
- Alternate Master Configuration with Integrated Solutions
- Internal Capacitor Provides Power to 1-Wire Slave
- Communication with Time Slots = Binary 0, 1
- Slaves Self-Clocked from Master Edges

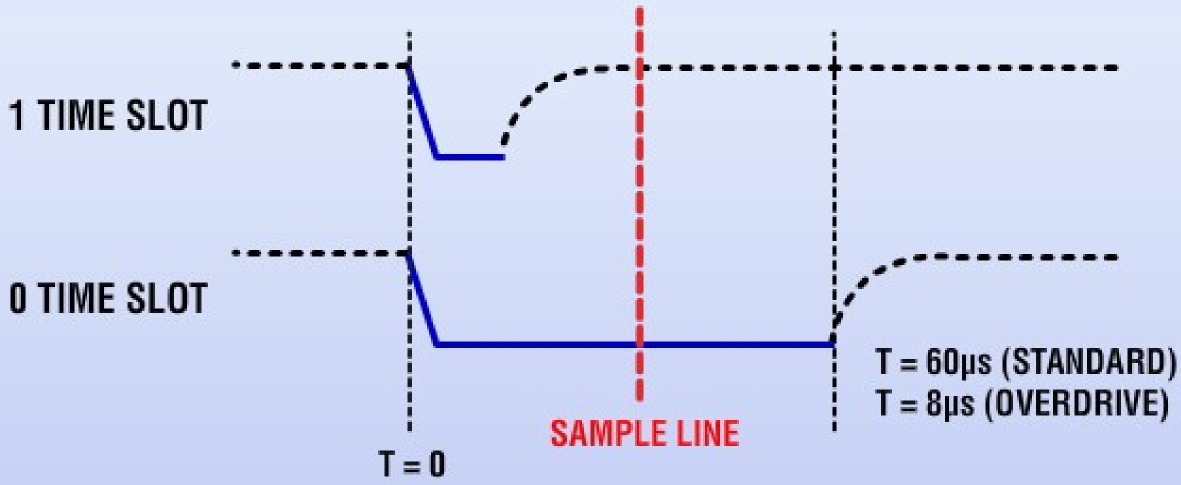


Master/Slave Configuration

Time Slots – podstawy

1-Wire Signaling—The Concept of Time Slots

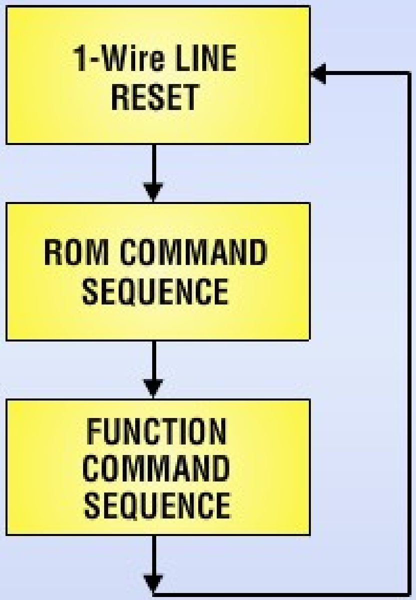
- Uses Controlled, Low-Duration Time Pulses to Encode the Binary 1s and 0s
  - Binary 1 Is Transmitted as a Short, Low Duration Time Slot
  - Binary 0 Is Transmitted as a Long, Low Duration Time Slot
- Time Slot (T)
  - Standard Speed: 60µs
  - Overdrive Speed: 8µs



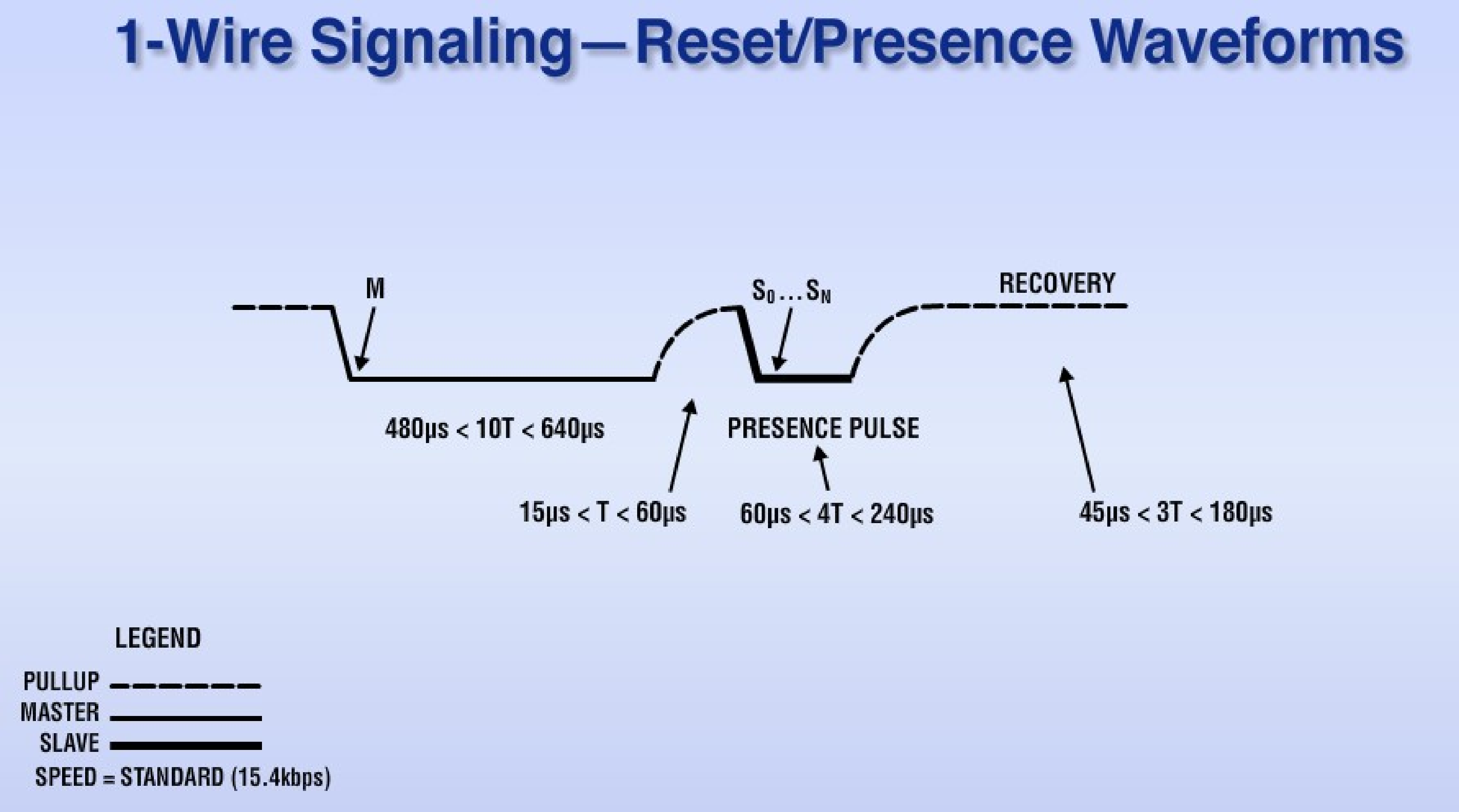
Kolejne fazy komunikacji

1-Wire Signaling—Waveforms

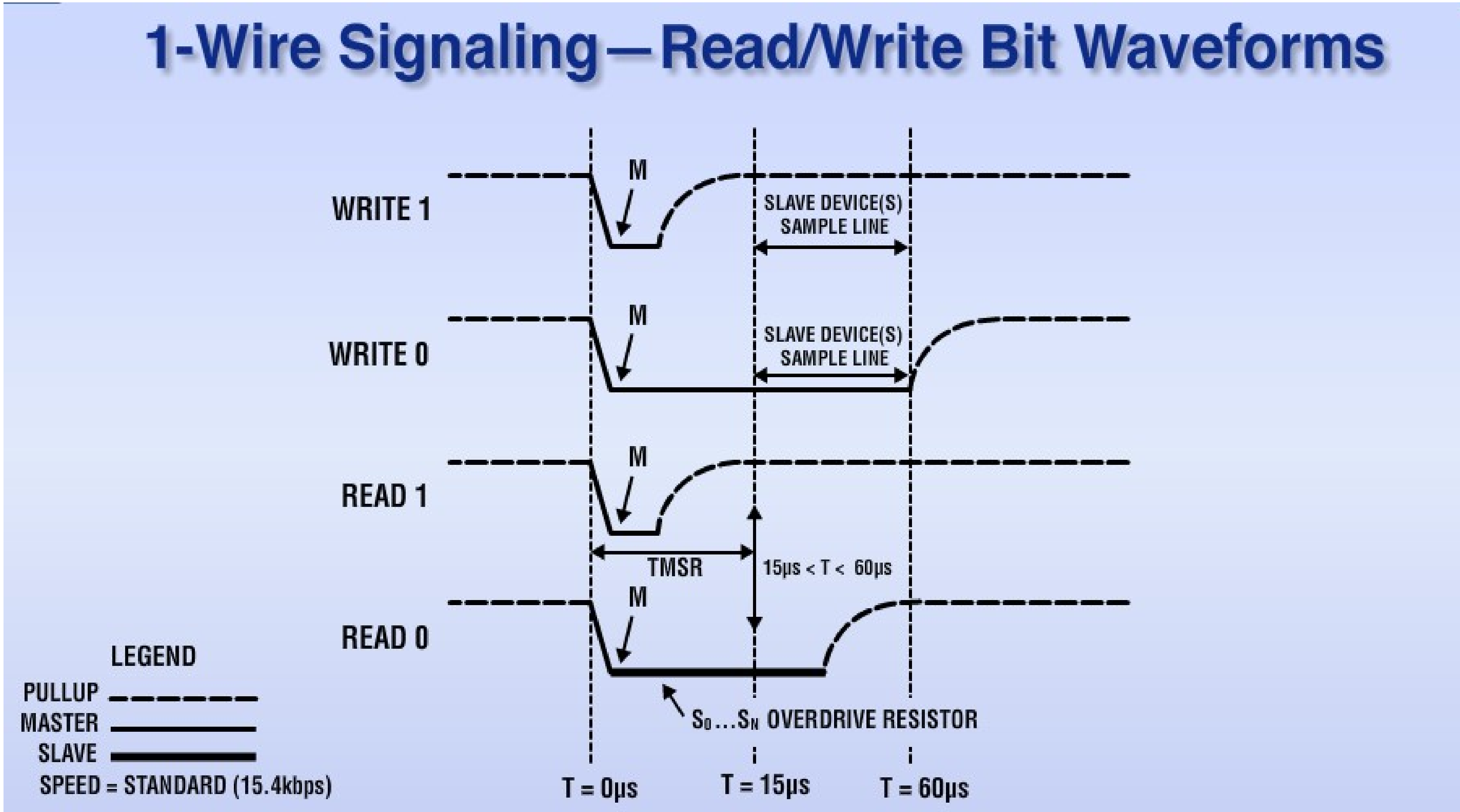
- Three-Phase Transaction
  - Device(s) Reset/Synchronization
  - Device Selection—ROM-Level Command
  - Device Function—Device-Level Command
- Speed
  - Standard (15.4kbps)
  - Overdrive (125kbps)



Synchronizacja do stanu RESET



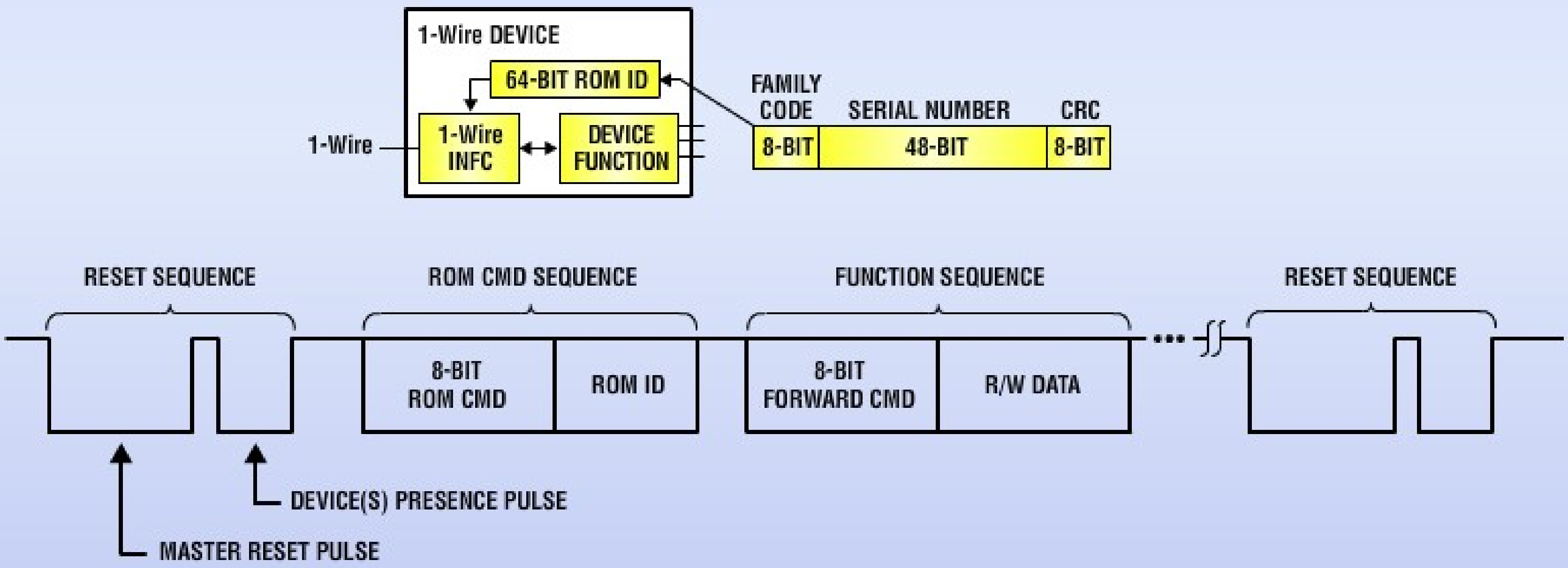
Time Slots zapisu/odczytu danych



Komendy

1-Wire Signaling—Commands

- Three-Phase Communication Sequence
- Host/Master Initiated and Controlled Bus Transactions
- Unique 64-Bit ROM ID in Every 1-Wire Device



Komendy dot. identyfikacji układów

1-Wire Signaling—ROM Level

- **ROM-Level Commands**
  - Skip ROM: Skip Device Selection for Single Device on Bus
  - Read ROM: Read 64-Bit ROM ID of Single Device on Bus
  - Match ROM: Identify Device on Bus with Known ROM ID
  - Resume: Restart Communication with Selected Device
  - Overdrive-Skip ROM: Skip Device Selection and Put Device in Overdrive Mode
  - Search ROM: Find Devices on the 1-Wire Bus

Przeszukiwanie magistrali

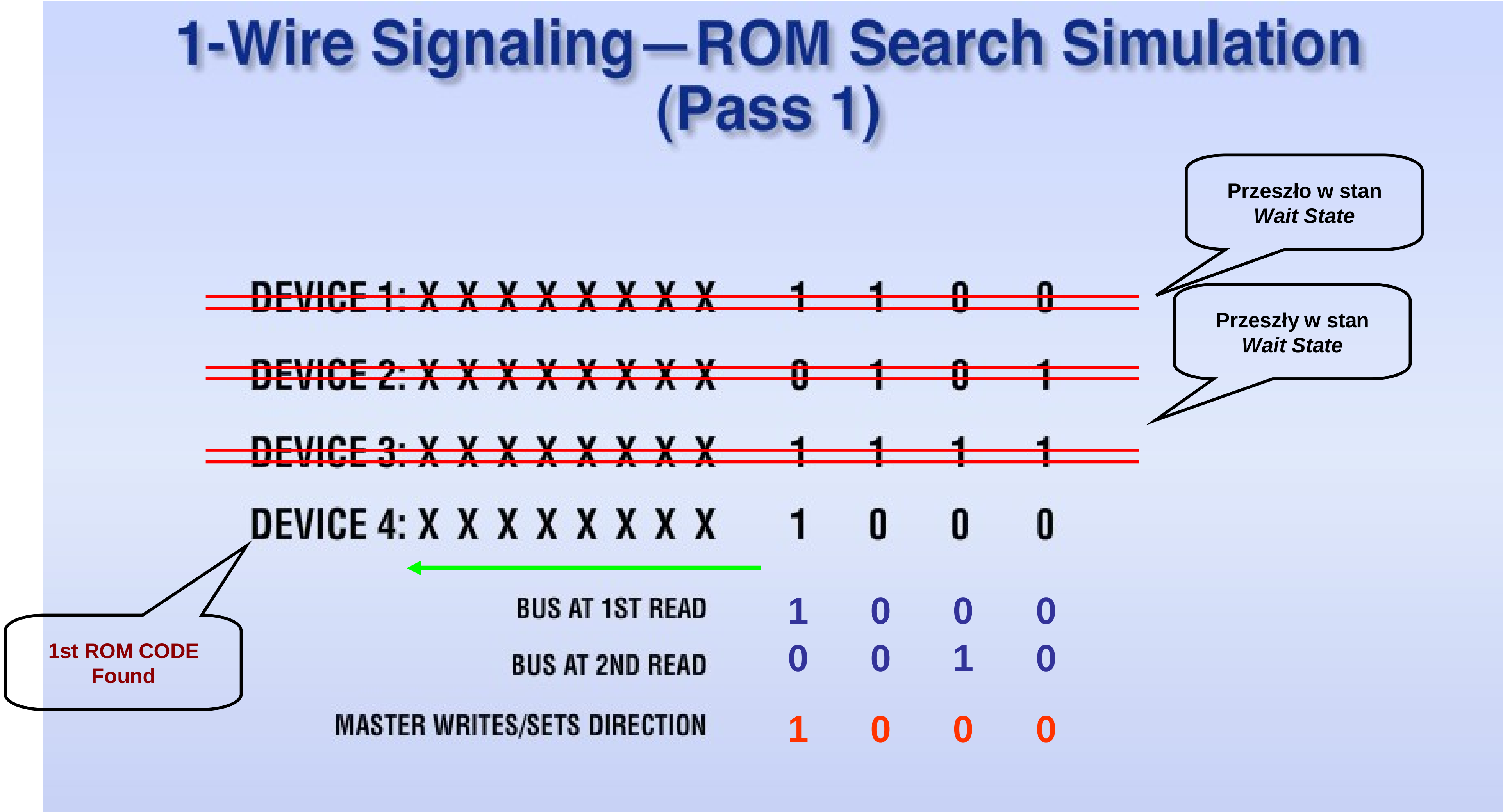
1-Wire Signaling—Search ROM Algorithm

- Sequence of Events
  - Master Initiates Search ROM Command Search Algorithm
  - Master Reads the First Bit Location Value (1st Read) for All Devices on Bus
  - Master Reads the Complement of the First Bit Location Value (2nd Read)
  - Master Compares the 1st Read and 2nd Read
  - Master Writes a Bit Back to Participating Devices (Write Direction Bit)
  - Participating Devices Compare the Bit Sent by the Master to the Value They Have
    - If Slave Has the Bit Value, It Continues to Participate
    - If the Slave Does Not Have the Bit Value, It Removes Itself from the Bus (into a Wait State)
- Master Repeats Sequence = “Read Bit”, “Read Bit Complement”, “Write Desired Direction Bit” 63 More Times to Identify the Entire ROM Code of One Slave Device

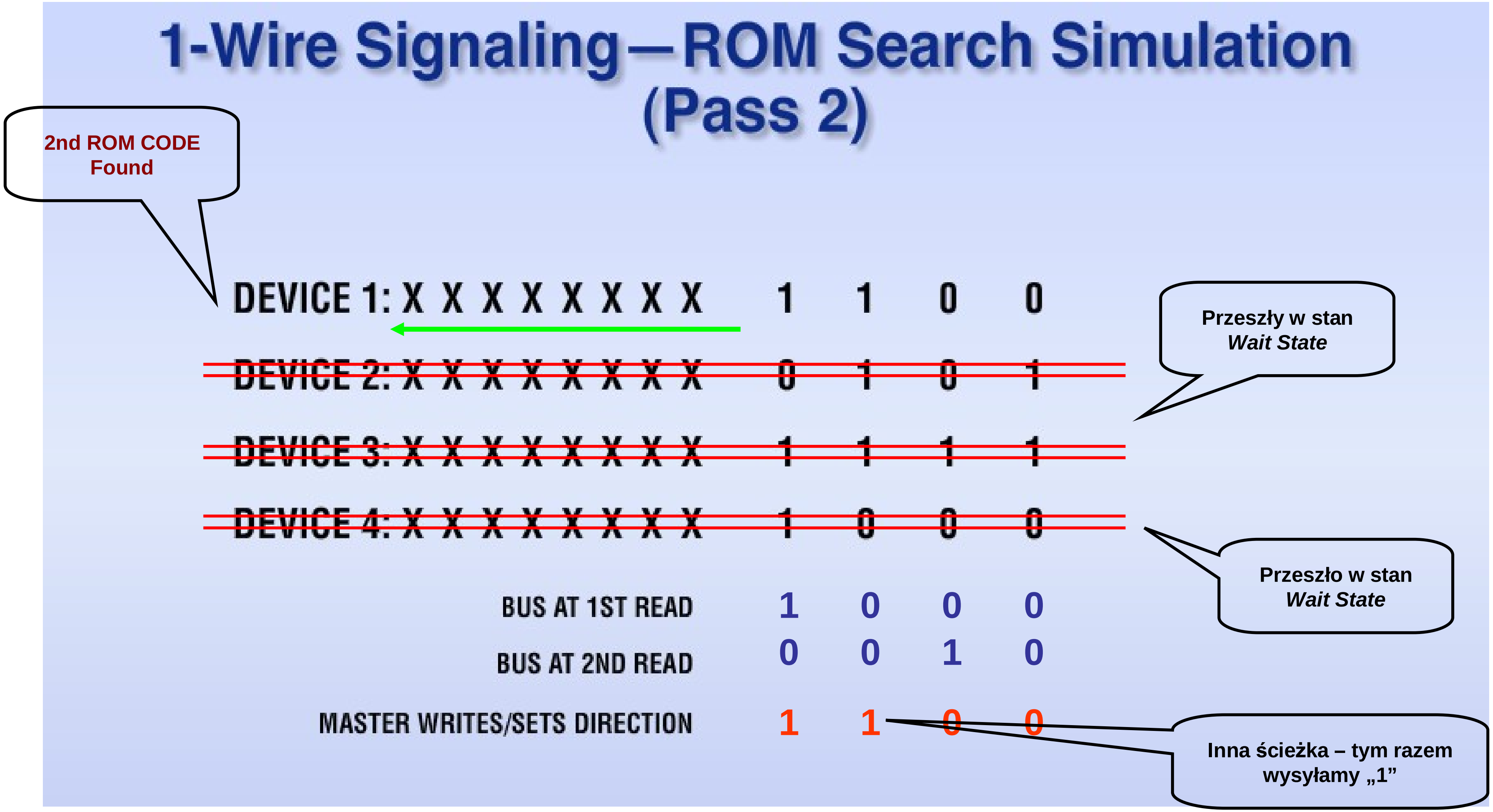
Lookup Table

Read 1 = Bit (True)	Read 2 = Bit (Complement)	Information Known
0	0	Condition 1: Some devices on bus have logic 1, others have logic 0 at bit location being read
0	1	Condition 2: All devices on bus have 0 at the bit location being read
1	0	Condition 3: All devices on bus have 1 at the bit location being read
1	1	Condition 4: No devices present

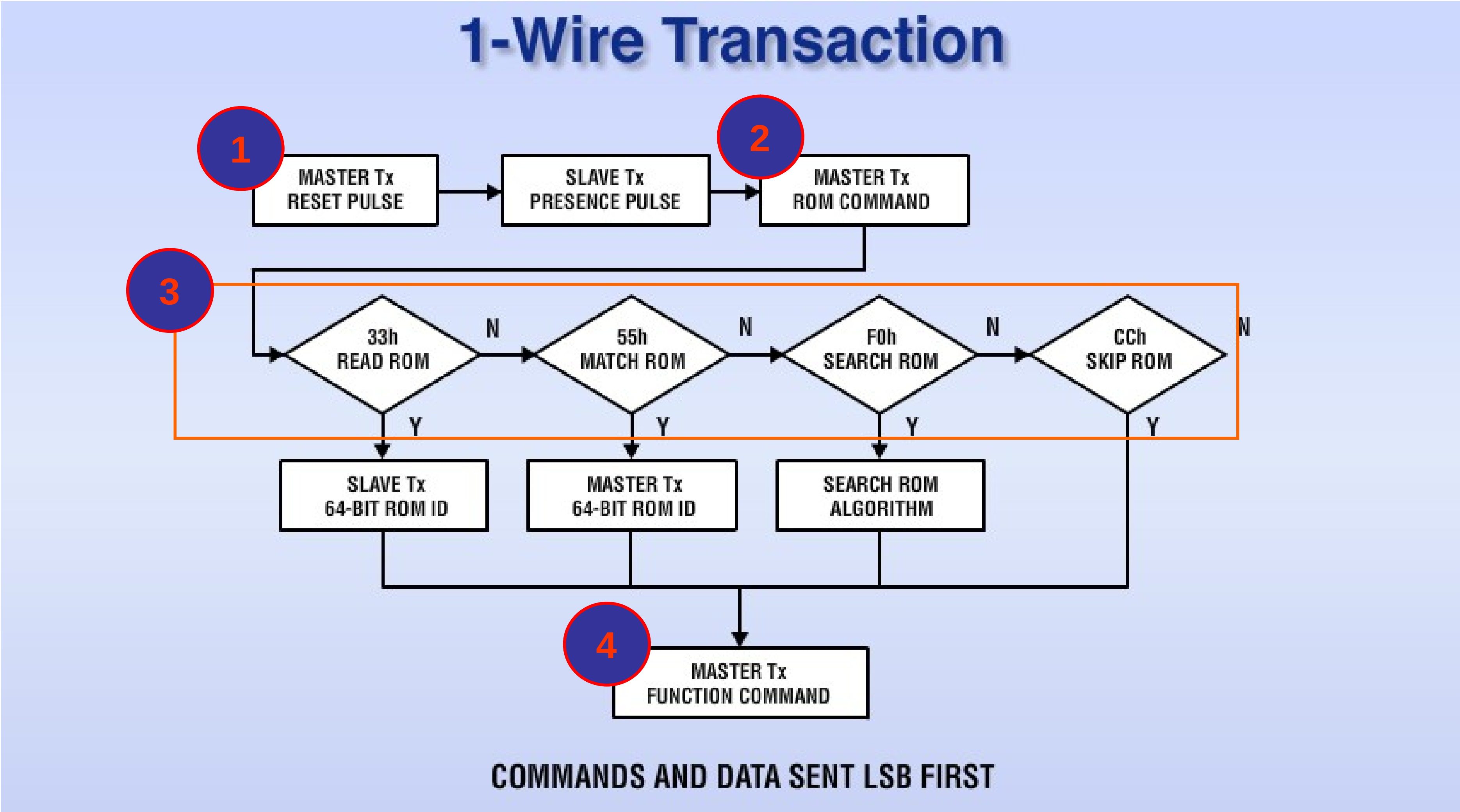
Przeszukiwanie magistrali – 1st Pass



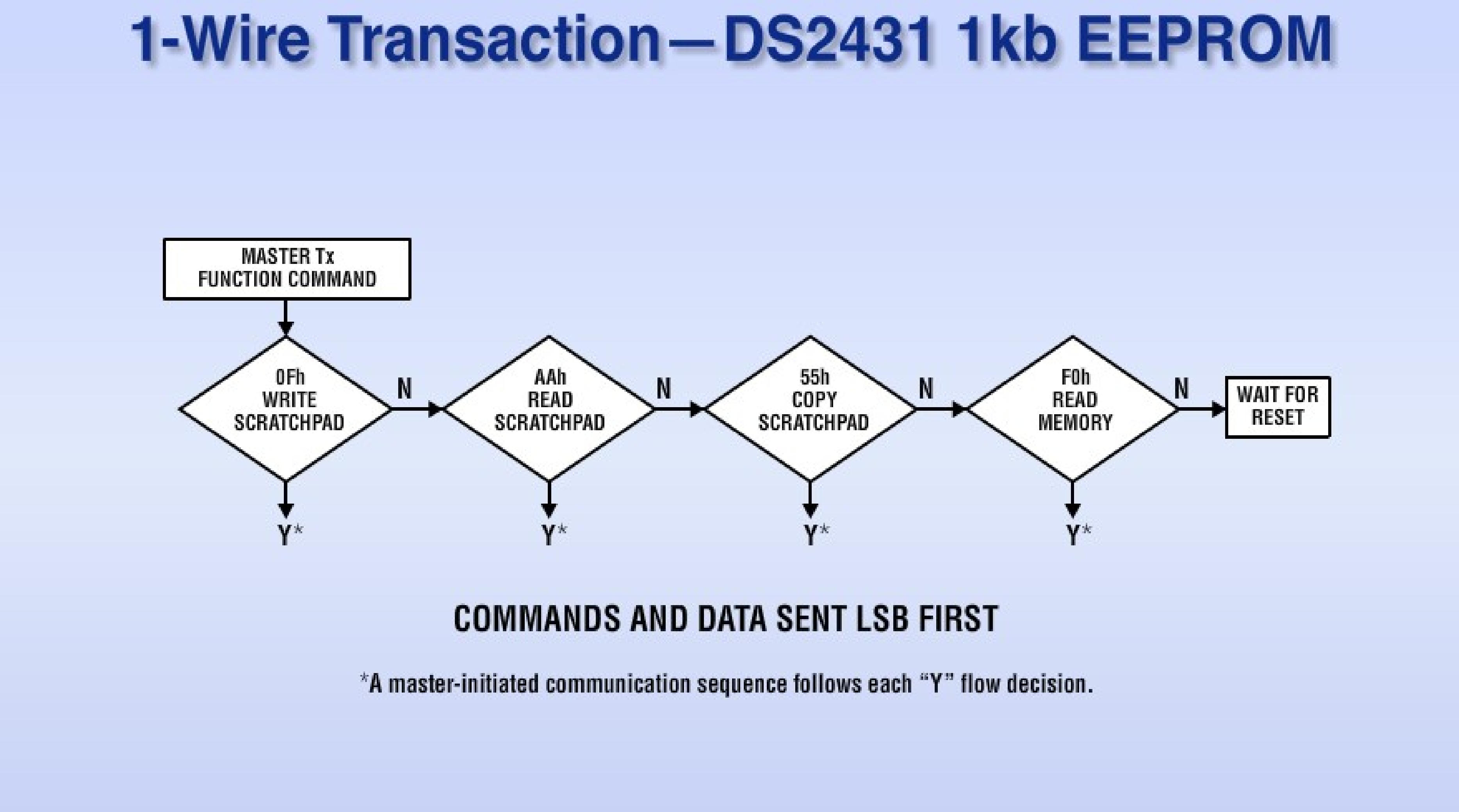
Przeszukiwanie magistrali – 2nd Pass



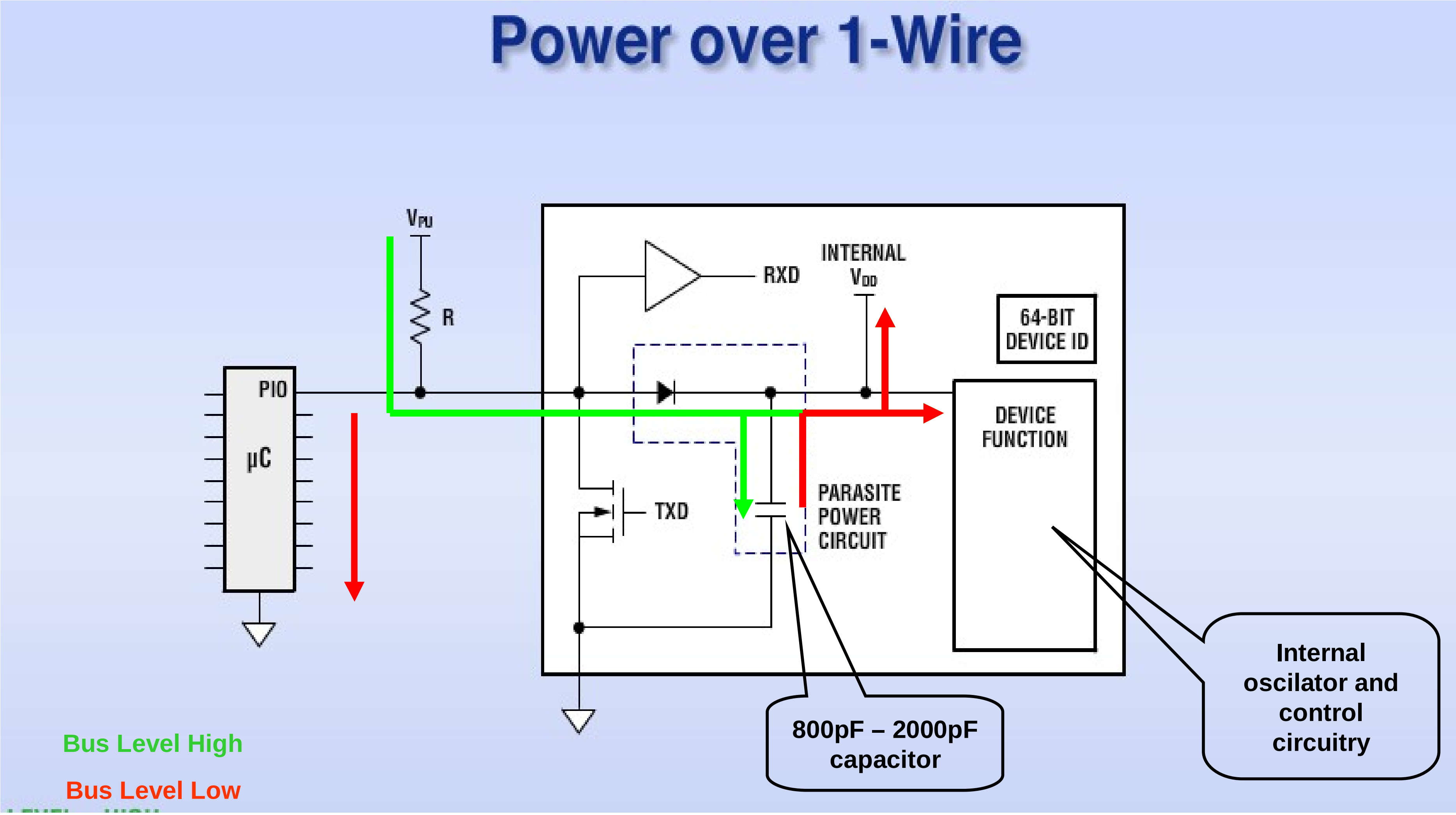
Wymiana danych



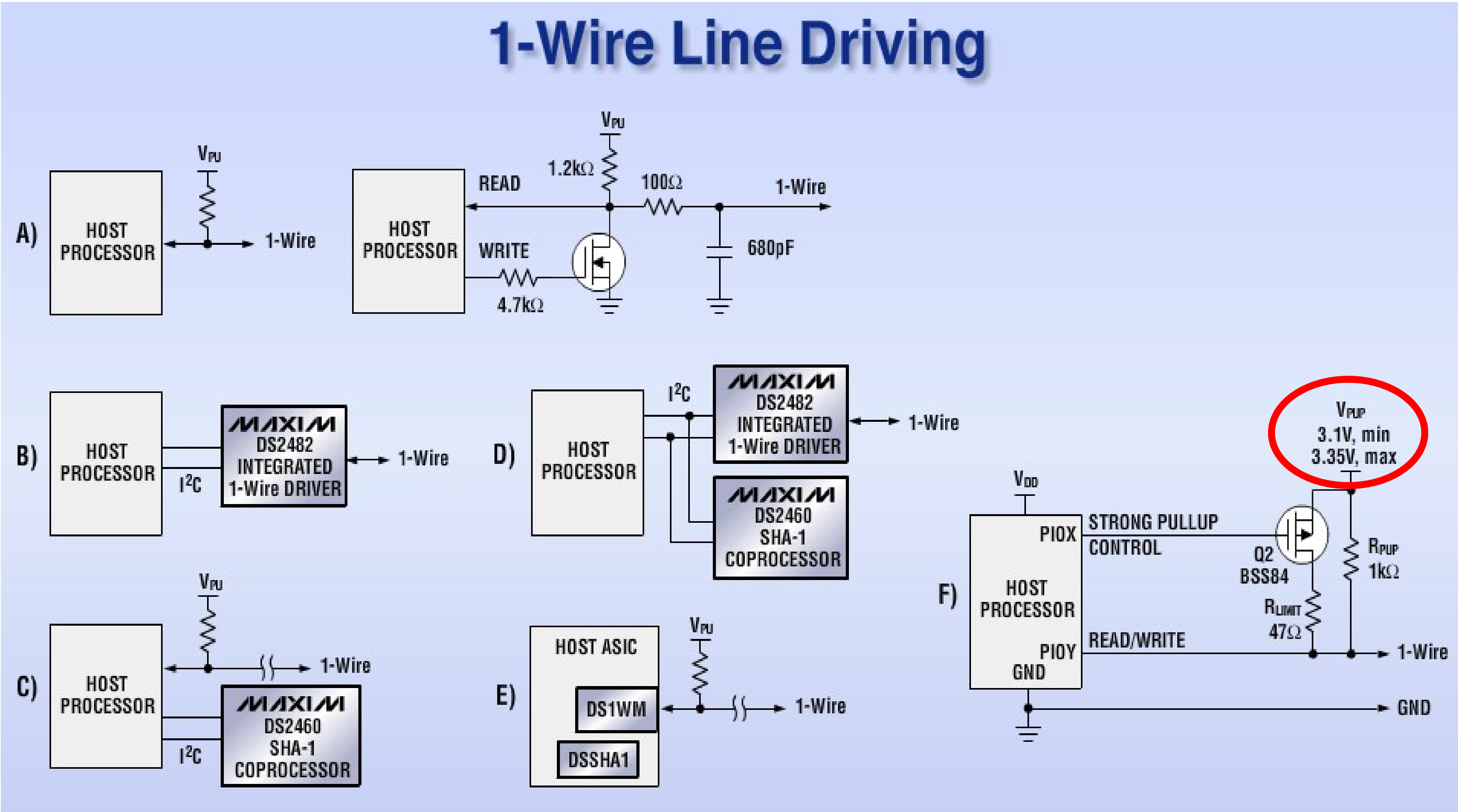
Wymiana danych – przykładowe komendy



Zasilanie układów z magistrali

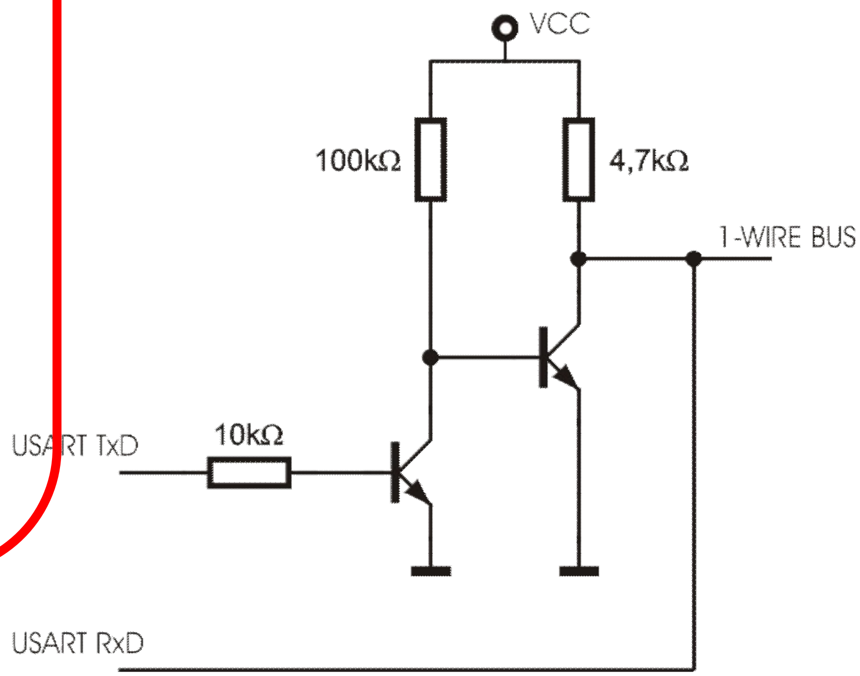


Implementacja 1-Wire w projekcie



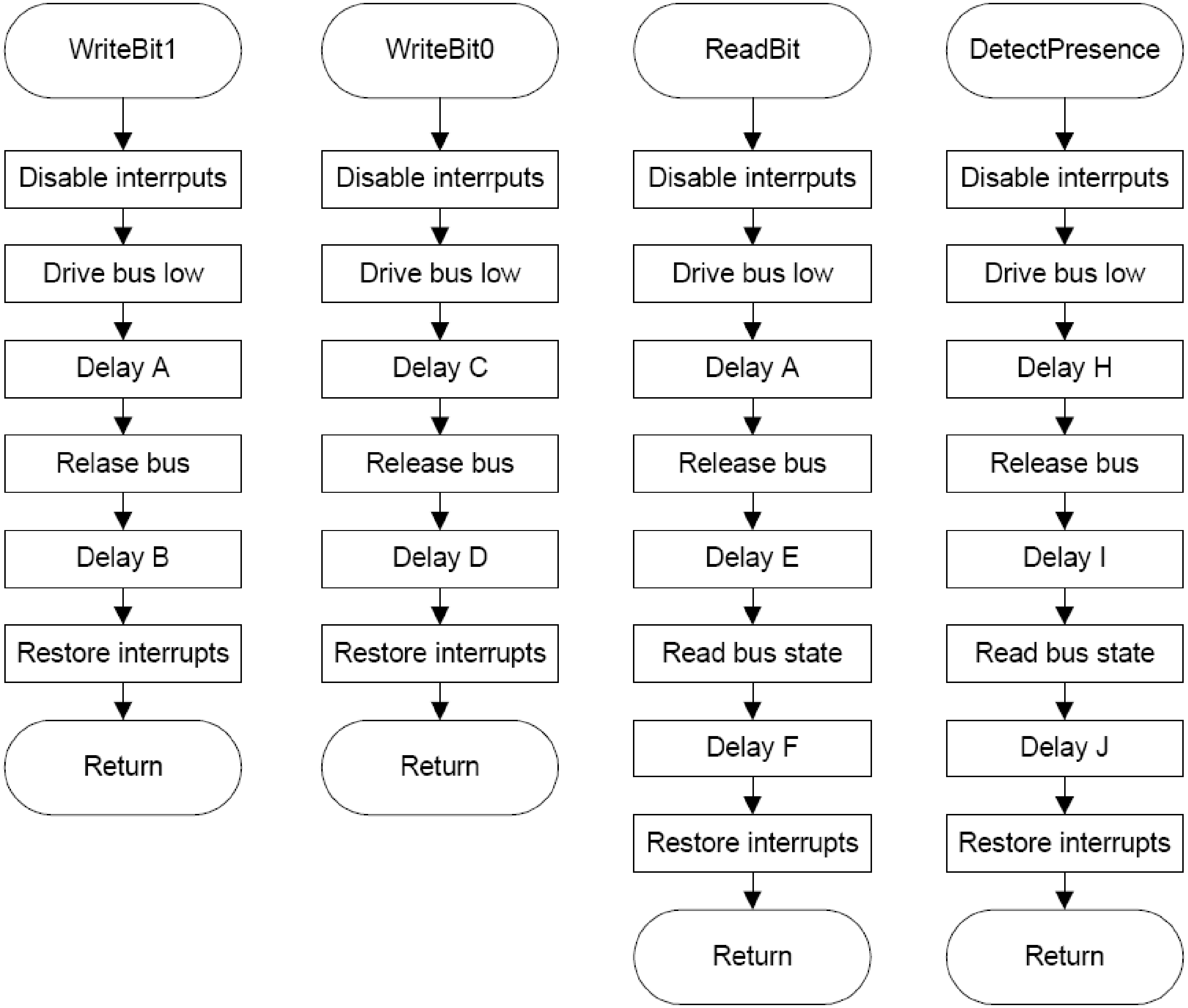
Implementacja 1-Wire w projekcie

- programowa emulacja magistrali
  - zmiany stanu oraz kierunku linii I/O,
  - generowanie opóźnień.
- wykorzystanie modułu USART
  - zarówno linia TxD jak i RxD podłączone do magistrali,
  - wymagany zewnętrzny bufor OC / OD (open-collector / open-drain) aby urządzenia slave mogły ściągnąć magistralę do zera gdy na wyjściu modułu UART wystawiono stan wysoki.
- zewnętrzny most 1-Wire
  - DS2482 (I2C **ó** 1-Wire),
  - DS2480 (UART **ó** 1-Wire).



zewnętrzny obwód OC dołączany do modułu UART kontrolera

Programowa emulacja 1-Wire



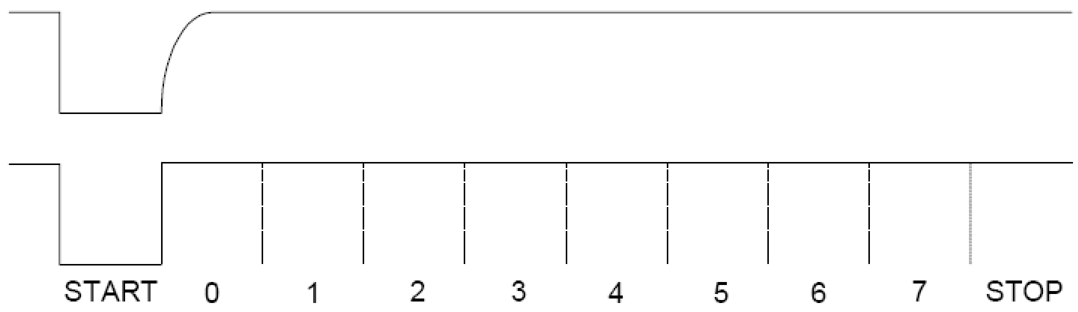
- Opóźnienia:
  - A => 6us
  - B => 64us
  - C => 60us
  - D => 10us
  - E => 9us
  - F => 55us
  - G => 0us
  - H => 480us
  - I => 70us
  - J => 410us

Wykorzystanie USART do emulacji 1-Wire

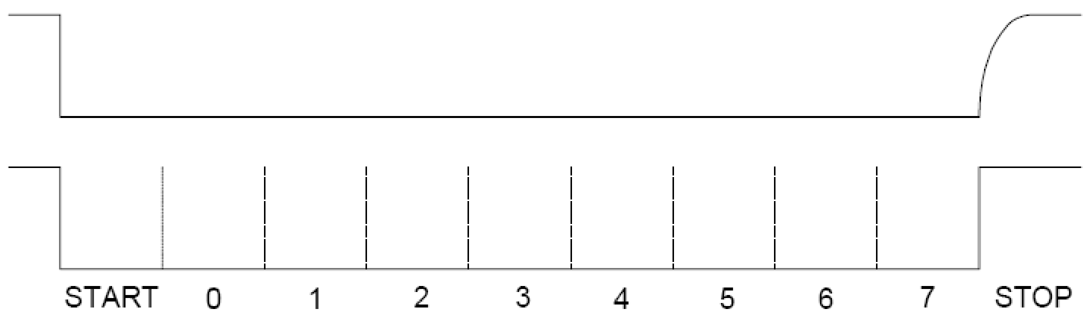
- ramka 8, N, 1 – jedna ramka UART używana do generowania pojedynczego bitu 1-Wire lub sekwencji RESET/PRESENCE
- standardowa prędkość pracy magistrali 1-Wire:
  - 15,4 kbps (~60usek. / pojedynczy bit)
- pojedynczy bit 1-Wire emuluje 10 bitów (st, 8b, stp) UART
  -> jaka BAUD RATE ??
- sekwencja RESET/PRESENCE -> około 10 razy wolniejsza
  -> jaka BAUD RATE??

Signal	**Baud Rate**	**Transmit value**	**Receive value**
Write 1	115200	FFh	FFh
Write 0	115200	00h	00h
Read	115200	FFh	FFh equals a ‘1’ bit Anything else equals a ‘0’ bit
Reset/Presence	9600	F0h	F0h equals no presence. Anything else equals presence.

Wykorzystanie USART do emulacji 1-Wire

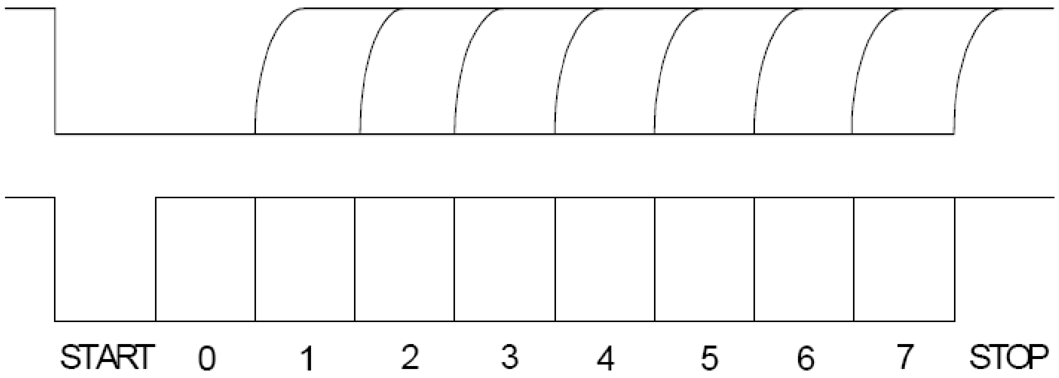


Zapis „1”

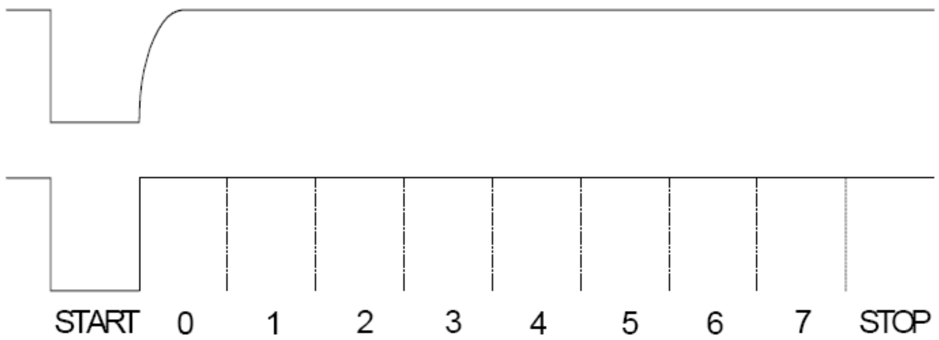


Zapis „0”

Wykorzystanie USART do emulacji 1-Wire

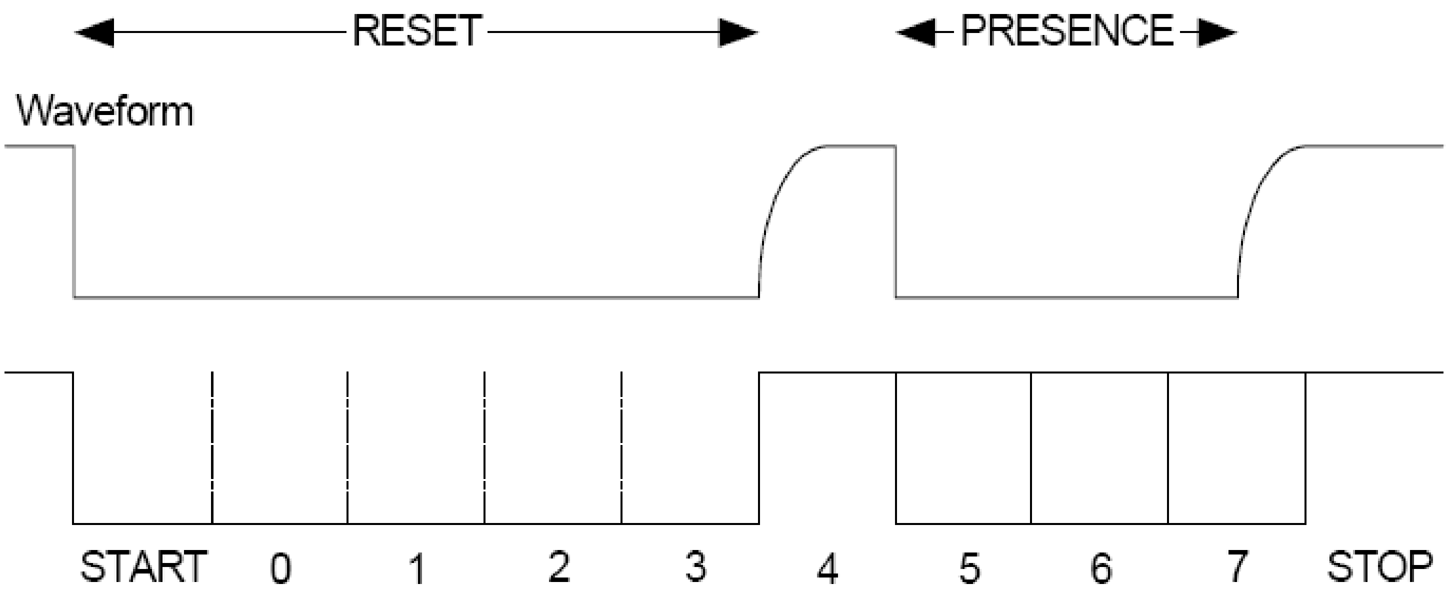


Odczyt „0”



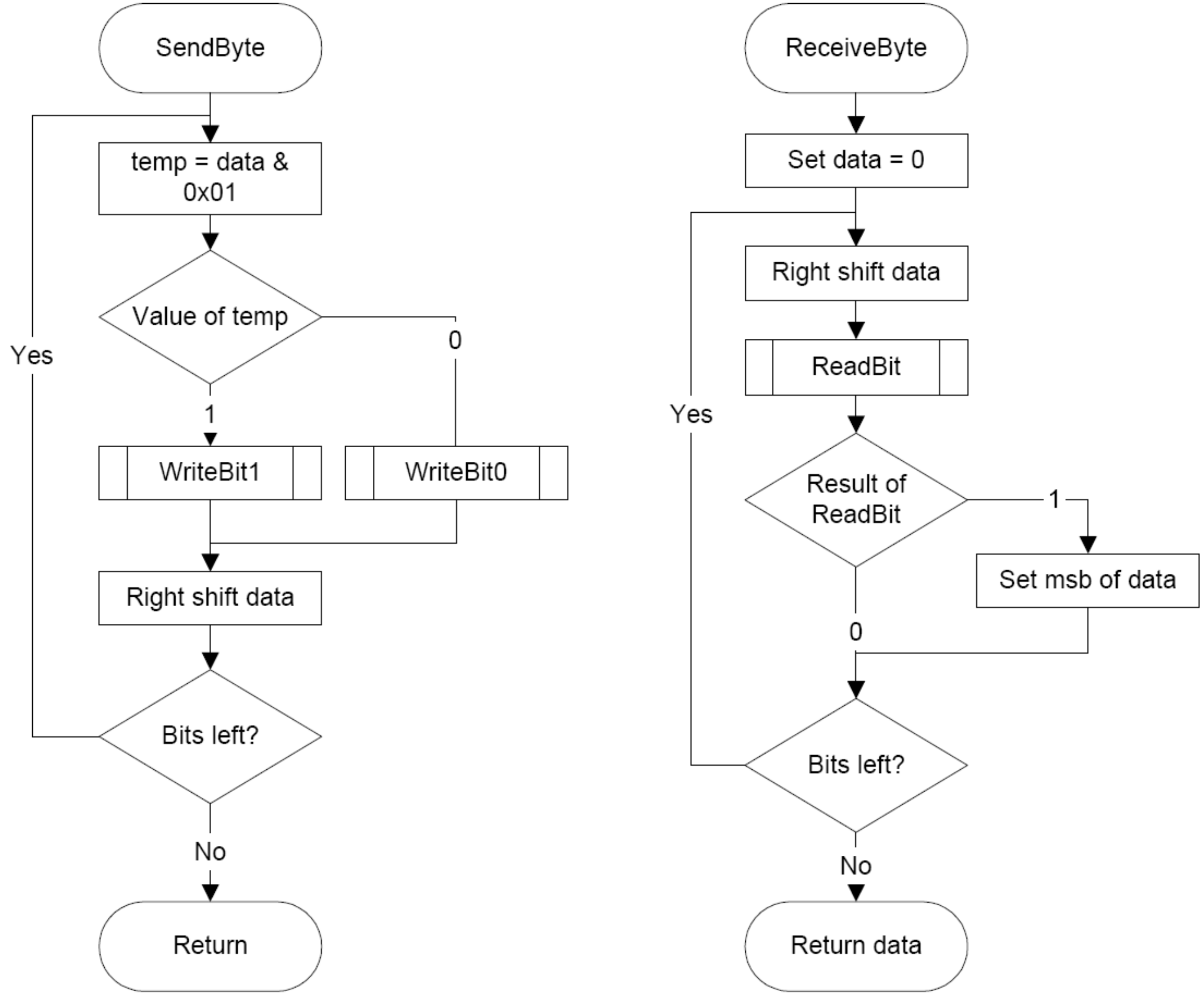
Odczyt „1”

Wykorzystanie USART do emulacji 1-Wire

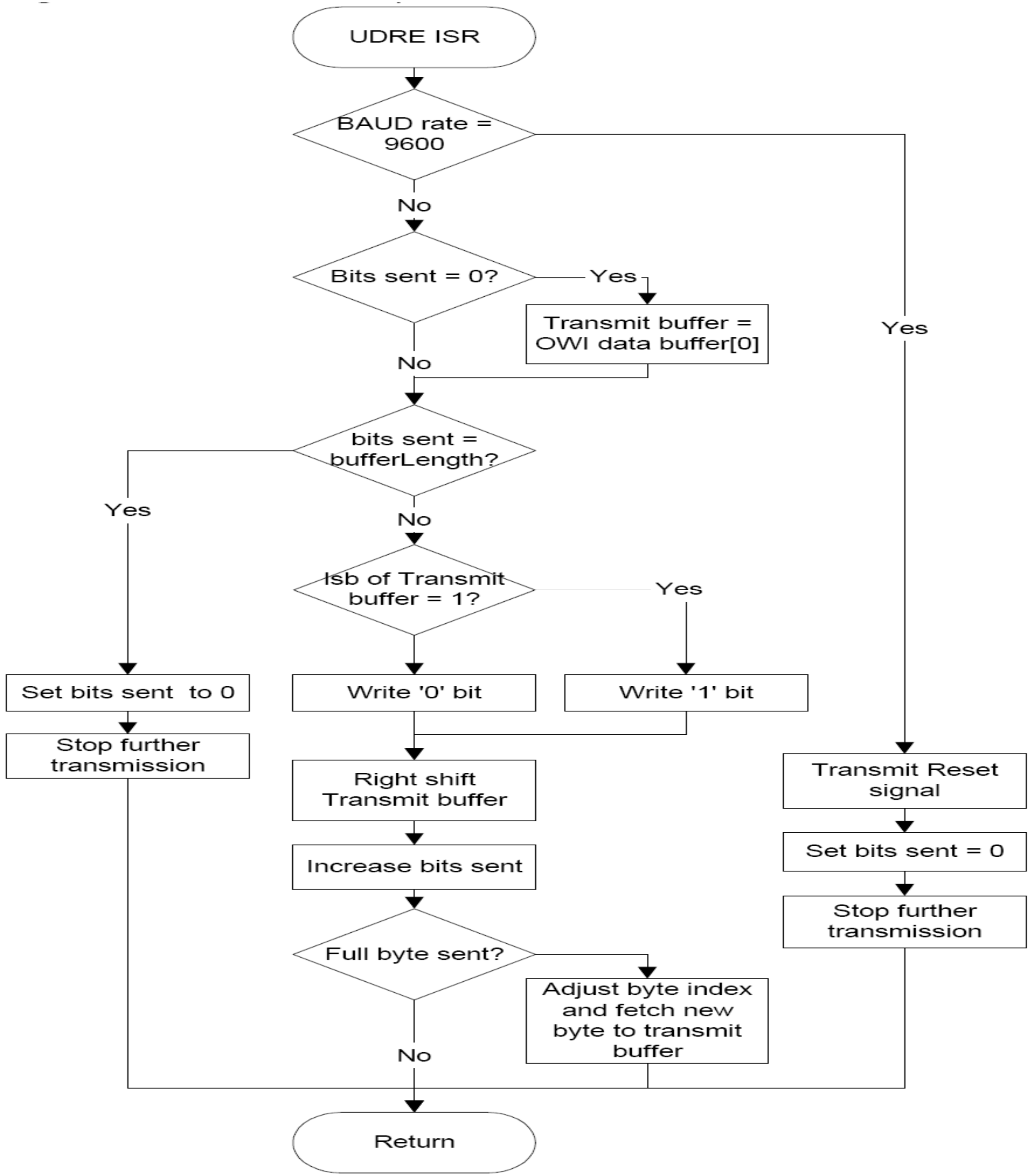


Sekwencja RESET / PRESENCE

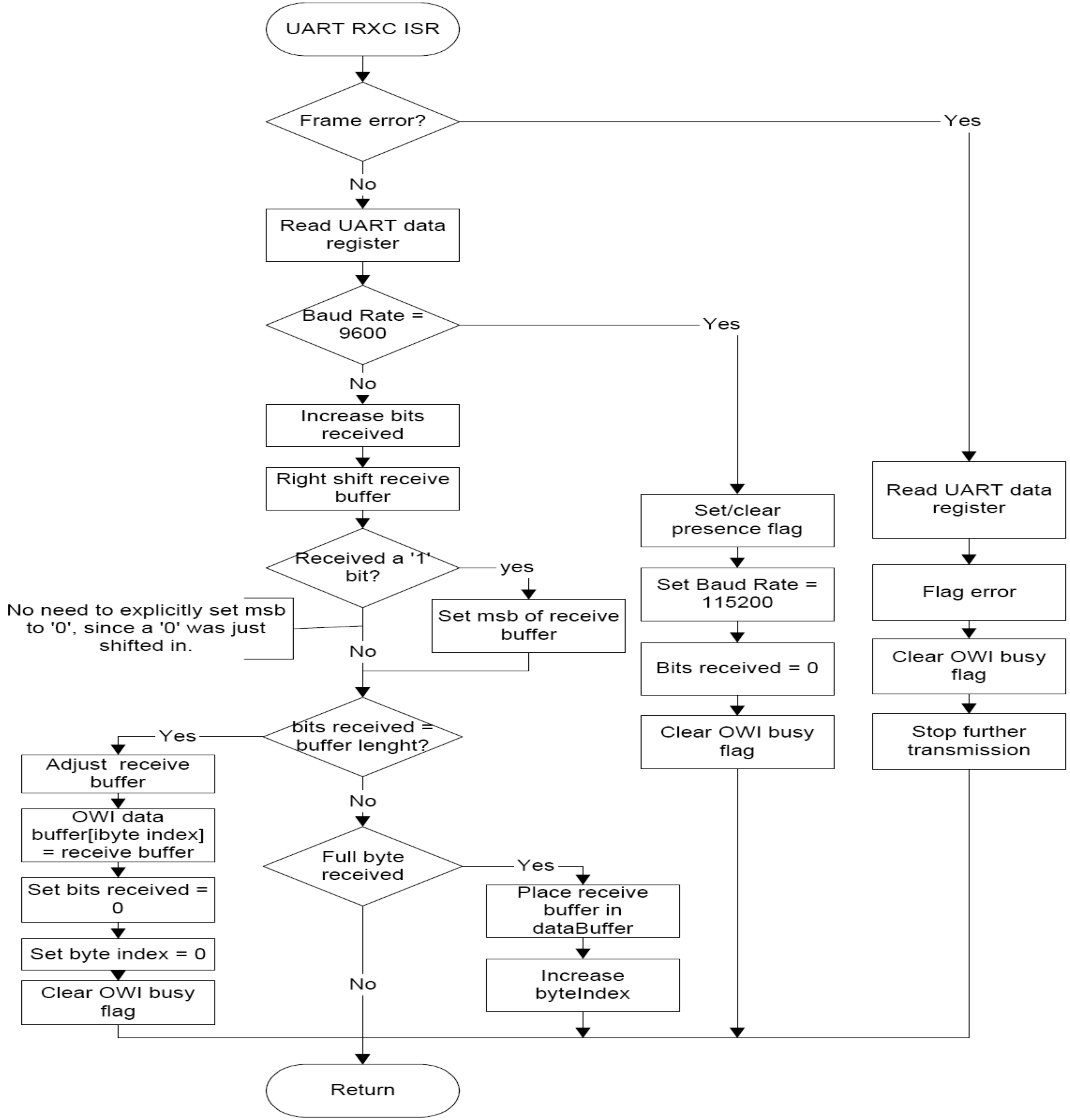
Wykorzystanie USART do emulacji 1-Wire



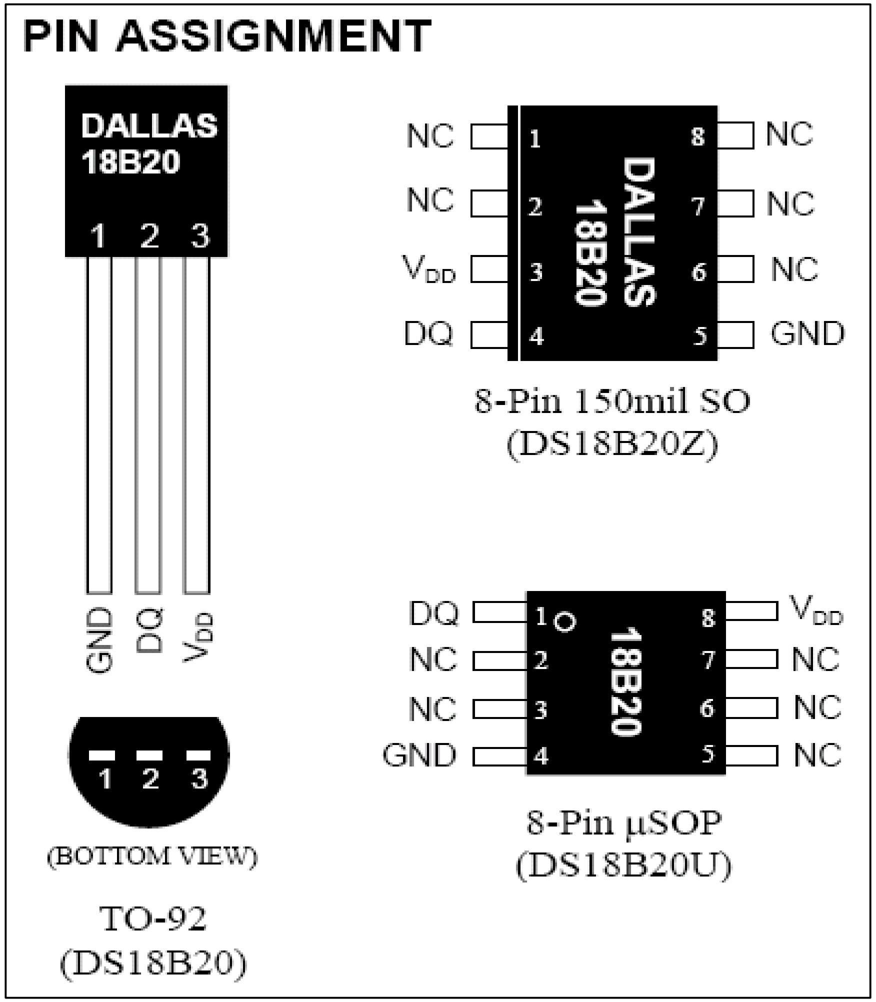
VVV 1-Wire z wykorzystaniem przerwań UART VVV



VVV 1-Wire z wykorzystaniem przerwań UART VVV



Komunikacja 1-Wire na przykładzie układu DS18B20



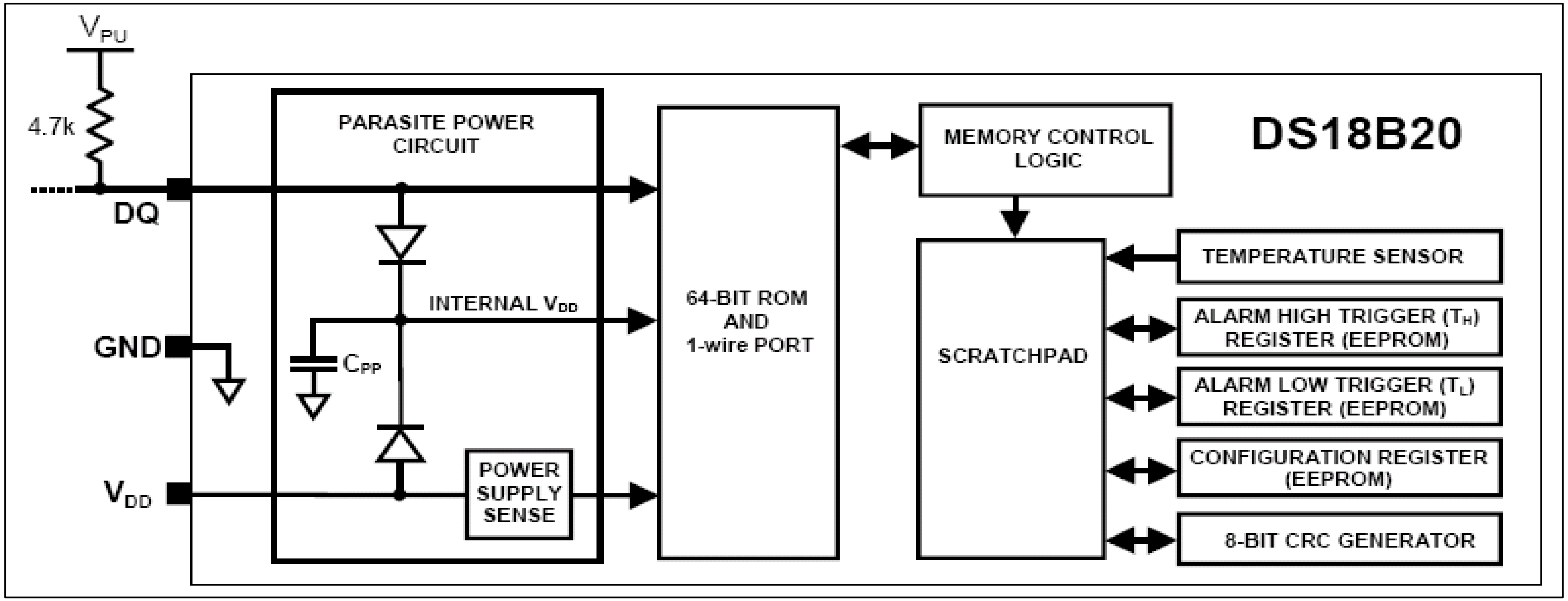
- DS18B20 – cyfrowy termometr z funkcją alarmu

- Podstawowe cechy urządzenia:
  - Zasilanie: 3.0V – 5.5V,
  - Zakres temperatur: -55^{O}C - 125^{O}C,
  - Dokładność 0,5^{O}C w dużym zakresie temperatury,
  - Programowalna rozdzielczość pomiaru od 9 do 12 bitów,
  - Czas konwersji – max. 750 msek.

źródło: DS18B20 Datasheet

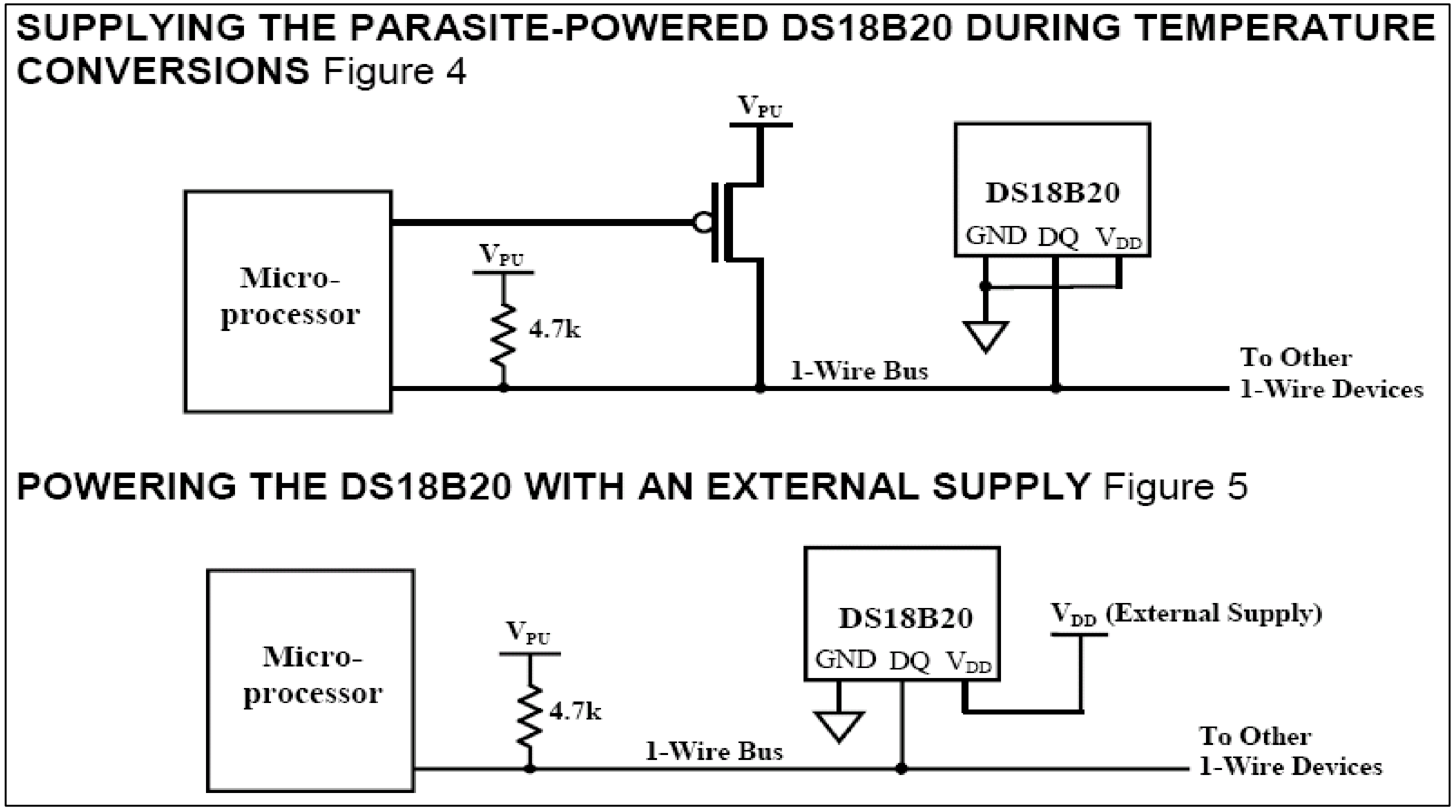
Komunikacja 1-Wire na przykładzie układu DS18B20

- Schemat blokowy urządzenia:



źródło: DS18B20 Datasheet

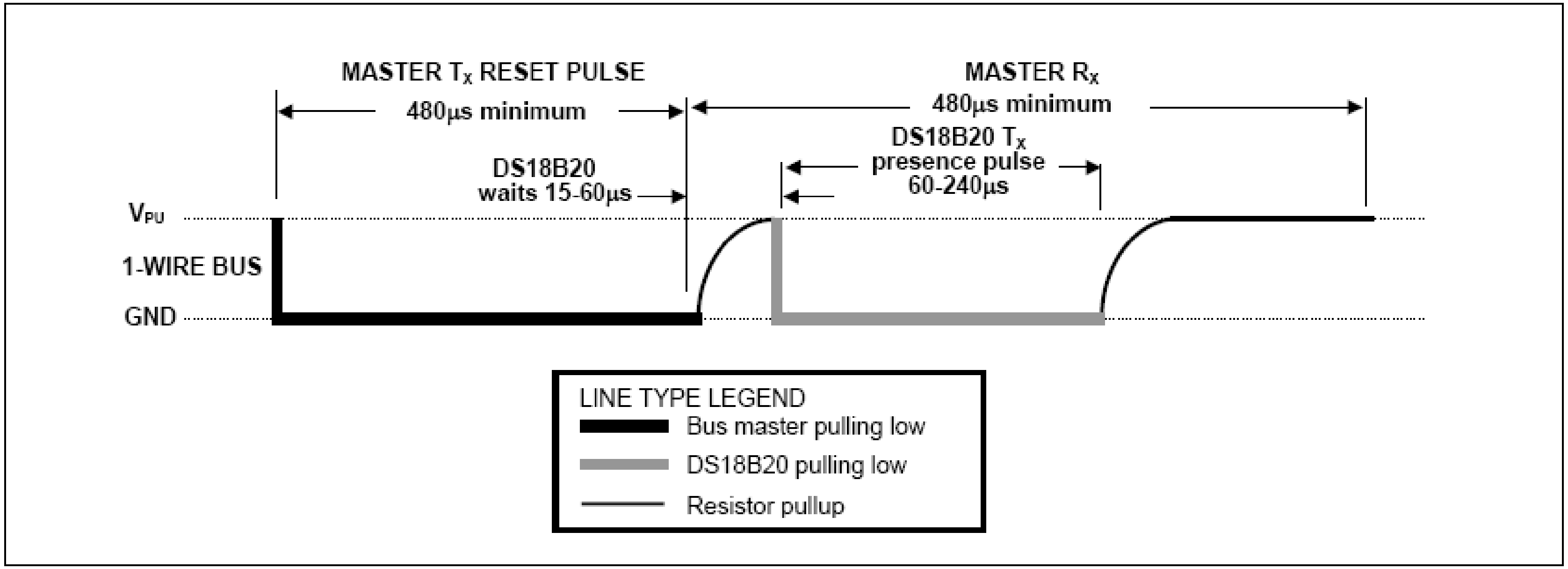
Komunikacja 1-Wire na przykładzie układu DS18B20



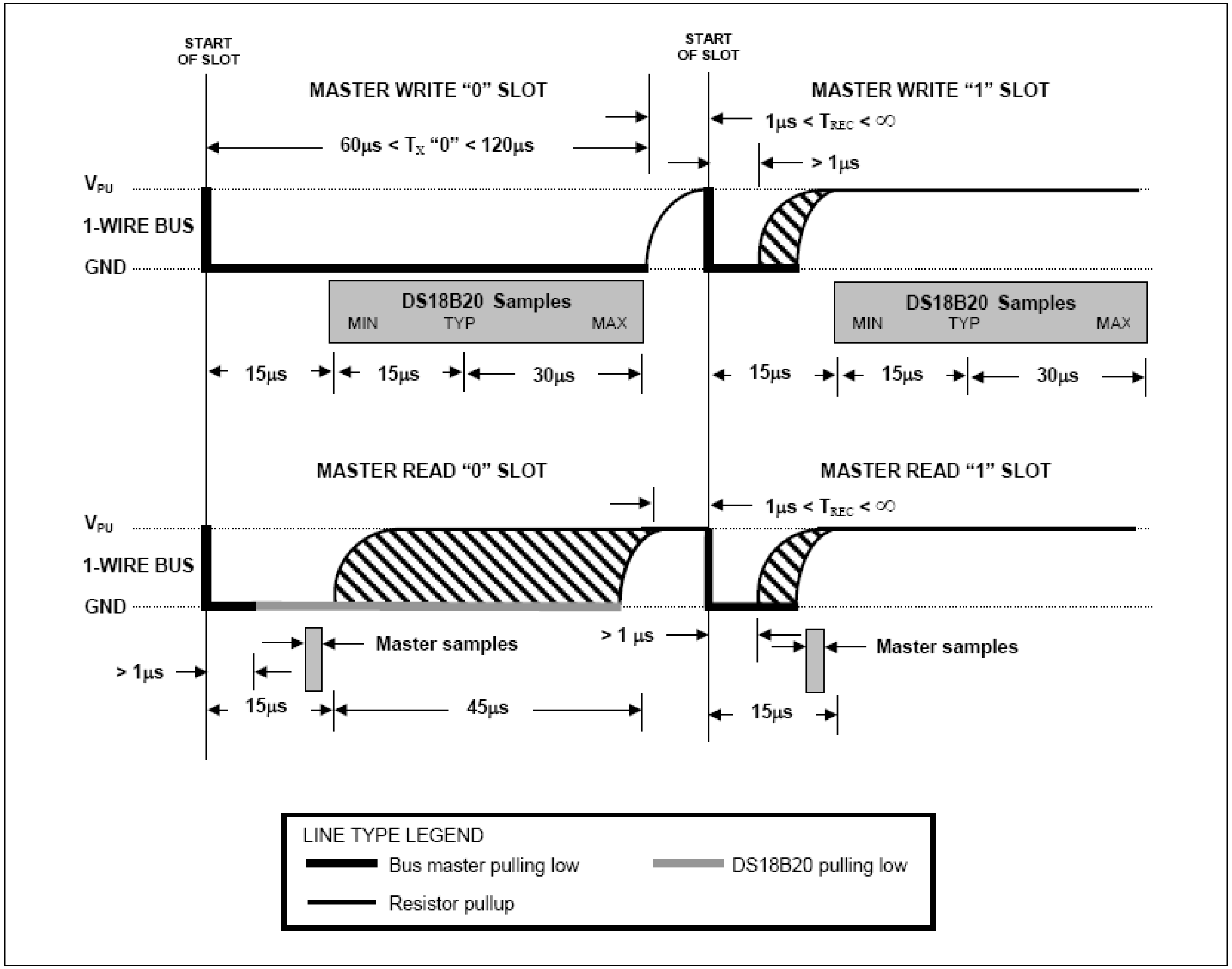
- Dwa rodzaje zasilania:
  - z linii danych – pewne ograniczenia, ale zmniejszona liczba przewodów,
  - z zewnętrznego źródła – dodatkowy przewód, zapewniona wygoda korzystania.

źródło: DS18B20 Datasheet

Inicjalizacja



Zapis / odczyt danych



Mapa pamięci układu, konfiguracja

SCRATCHPAD (POWER-UP STATE)

Byte 0	Temperature LSB (50h) (85°C)
Byte 1	Temperature MSB (05h)
Byte 2	T_H Register or User Byte 1*
Byte 3	T_L Register or User Byte 2*
Byte 4	Configuration Register*
Byte 5	Reserved (FFh)
Byte 6	Reserved
Byte 7	Reserved (10h)
Byte 8	CRC*

**Power-up state depends on value(s) stored in EEPROM.*

EEPROM

T_H Register or User Byte 1
T_L Register or User Byte 2
Configuration Register

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	R1	R0	1	1	1	1	1

R1	R0	RESOLUTION (BITS)	MAX CONVERSION TIME	
0	0	9	93.75ms	(t_{CONV}/8)
0	1	10	187.5ms	(t_{CONV}/4)
1	0	11	375ms	(t_{CONV}/2)
1	1	12	750ms	(t_{CONV})

Odczyt temperatury

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	**BIT 14**	**BIT 13**	**BIT 12**	**BIT 11**	**BIT 10**	**BIT 9**	**BIT 8**
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

Rejestr Temperatury

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

Obsługiwane komendy

COMMAND	DESCRIPTION	PROTOCOL	1-Wire BUS ACTIVITYAFTER COMMAND IS ISSUED	NOTES
TEMPERATURE CONVERSION COMMANDS				
Convert T	Initiates temperature conversion.	44h	DS18B20 transmits conversion status to master (not applicable for parasite-powered DS18B20s).	1
MEMORY COMMANDS				
Read Scratchpad	Reads the entire scratchpad including the CRC byte.	BEh	DS18B20 transmits up to 9 data bytes to master.	2
Write Scratchpad	Writes data into scratchpad bytes 2, 3, and 4 (T_H, T_L, and configuration registers).	4Eh	Master transmits 3 data bytes to DS18B20.	3
Copy Scratchpad	Copies T_H, T_L, and configuration register data from the scratchpad to EEPROM.	48h	None	1
Recall E^2	Recalls T_H, T_L, and configuration register data from EEPROM to the scratchpad.	B8h	DS18B20 transmits recall status to master.	
Read Power Supply	Signals DS18B20 power supply mode to the master.	B4h	DS18B20 transmits supply status to master.	

Note 1: For parasite-powered DS18B20s, the master must enable a strong pullup on the 1-Wire bus during temperature conversions and copies from the scratchpad to EEPROM. No other bus activity may take place during this time.
Note 2: The master can interrupt the transmission of data at any time by issuing a reset.
Note 3: All three bytes must be written before a reset is issued.

Operation example 1

DS18B20 OPERATION EXAMPLE 1

In this example there are multiple DS18B20s on the bus and they are using parasite power. The bus master initiates a temperature conversion in a specific DS18B20 and then reads its scratchpad and recalculates the CRC to verify the data.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	44h	Master issues Convert T command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for the duration of the conversion (t_{CONV}).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.

Operation example 2

DS18B20 OPERATION EXAMPLE 2

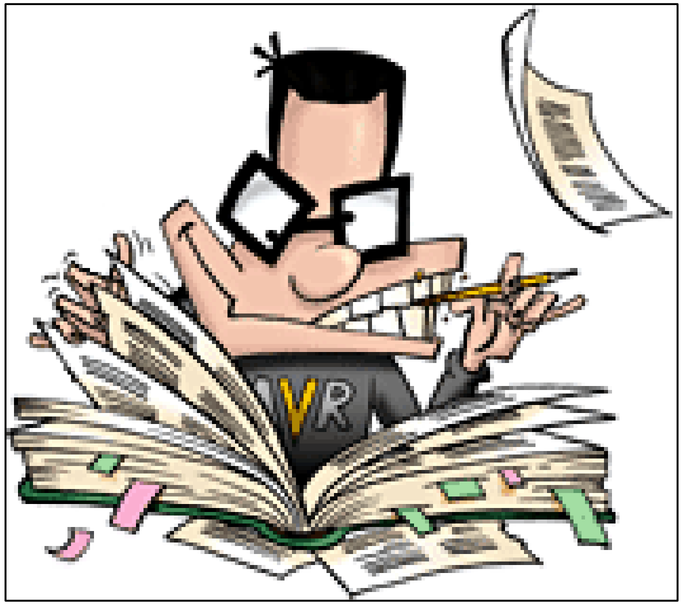
In this example there is only one DS18B20 on the bus and it is using parasite power. The master writes to the T_H, T_L, and configuration registers in the DS18B20 scratchpad and then reads the scratchpad and recalculates the CRC to verify the data. The master then copies the scratchpad contents to EEPROM.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	4Eh	Master issues Write Scratchpad command.
Tx	3 data bytes	Master sends three data bytes to scratchpad (T_H, T_L, and config).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	48h	Master issues Copy Scratchpad command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for at least 10ms while copy operation is in progress.

Dodatkowe informacje

- http://www.maxim-ic.com/auto_info.cfm - 1-Wire and iButton Main Page
  - http://www.maxim-ic.com/products/1-wire/ - 1-Wire Homepage
  - http://www.maxim-ic.com/products/ibutton/ - iButton Homepage
- http://www.maxim-ic.com/design_guides/en/1_WIRE_PRODUCTS_4.pdf - Maxim 1-Wire Design Guide
- http://www.maxim-ic.com/an_prodline2.cfm/prodline/21 - Maxim 1-Wire Application Notes
  - AN126: 1-Wire Communiaction Through Software
  - AN187: 1-Wire Search Algorithm
  - AN214: Using a UART to Implement a 1-Wire Bus Master
  - AN937: Book of iButton Standards
- Atmel Application Note AVR318: Dallas 1-Wire Master:
  - http://atmel.com/dyn/resources/prod_documents/doc2579.pdf

Pytania?



Pytania???

Politechnika Łódzka

Instytut Elektroniki

Dziękuję za uwagę.