ECE 372 – Microcontroller Design

UARTs and Peripheral Pin Mapping

The University of Arizona
Tucson Arizona

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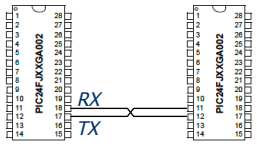
UART

- Universal Asynchronous Receiver Transmitter (UART)
  - Utilize serial transmission to communicate between two components (e.g. PICs, desktop, modem)
  - Communication must occur on a mutually known rate
    - *baud rate* (bits per second)
  - Minimally requires only two connection
    - *TX*: Transmitting
    - *RX*: Receiving



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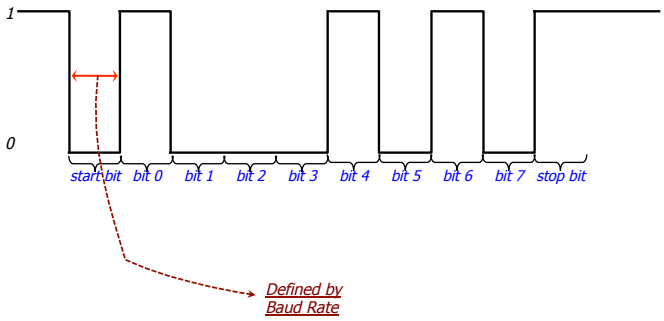
UART

- Universal Asynchronous Receiver Transmitter (UART)



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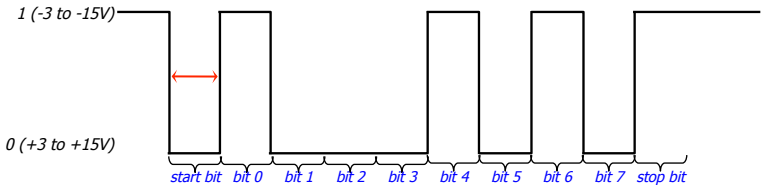
UART

- RS-232/EIA232
  - Defines both serial communication protocol and voltage levels
  - Different voltage levels allows for long range communication between devices
    - 0: +3 to +15 V
    - 1: -3 to -15 V
  - Requires conversion chip for interfacing PIC with desktop computer
    - May also require a NULL modem cable/adapter



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UART Configuration and Reprogrammable Port Mappings

- Basic UART Configuration
  - UxMODE: *configure transmission format*
    - PDSEL: number of bits (8/9) and parity (no/even/odd)
    - STSEL: stop bits (1/2)
    - UARTEN: enable UART
    - BRGH: set baud rate generator to (high/low) speed
  - UxSTA: *configure how interrupts and generated*
    - UTXEN: enable transmission
    - UTXISEL: controls when UxTXIF is set
    - URXISEL: controls when UxRXIF is set
  - UxBRG: *configure baud rate*
    - PORT : Value read directly from the port
  - UxRXREG: reads received characters from receive buffer
    - Receive buffers stores last four received characters in FIFO
  - UxTXREG: write characters to transmit to transmit buffer

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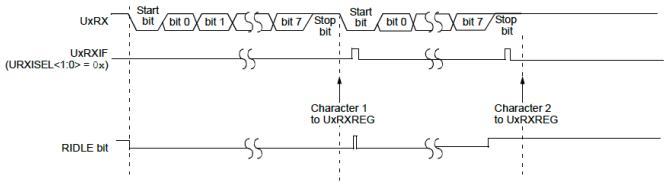
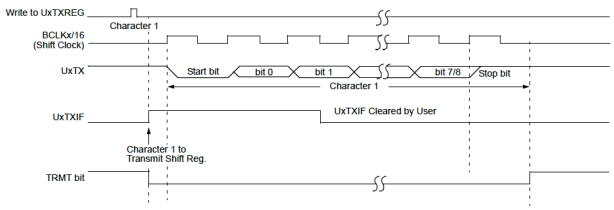
UART Configuration and Reprogrammable Port Mappings

- UART Receive (8N1)



- UART Transmit (8N1)



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UART Configuration

- UART Baud Rate Configuration
  - BRGH = 0
    - Baud Rate = F_{CY} / (16 * (UxBRG + 1))
    - UxBRG = F_{CY} / (16 * Baud Rate) - 1
    - Example: Baud Rate = 115200
      - F_{CY} = (7372800 * 4) / 2
      - F_{CY} = 14745600
      - UxBRG = 14745600 / (16*115200) – 1
      - UxBRG = 7
  - BRGH = 1
    - Baud Rate = F_{CY} / (4 * (UxBRG + 1))
    - UxBRG = F_{CY} / (4 * Baud Rate) - 1
    - Example: Baud Rate = 115200
      - F_{CY} = (7372800 * 4) / 2
      - F_{CY} = 14745600
      - UxBRG = 14745600 / (4*115200) – 1
      - UxBRG = 31

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UART Configuration and Reprogrammable Port Mappings

- UART Baud Rate Error
  - Baud rate may not be exact depending in desired rate and F_{CY} frequency
  - Can calculate baud rate error
  - BRGH = 0
    - UxBRG = 7
    - Baud Rate = F_{CY} / (16 * (UxBRG + 1))
    - Baud Rate = 14745600 / (16 * 8)
    - Baud Rate = 115200
    - Baud Rate Error = (115200 – 115200)/115200 = 0%
  - BRGH = 1
    - UxBRG = 31
    - Baud Rate = F_{CY} / (4 * (UxBRG + 1))
    - Baud Rate = 14745600 / (4 * 32)
    - Baud Rate = 115200

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UART Configuration and Reprogrammable Port Mappings

- UART Baud Rate Error

Table 21-1: UART Baud Rates (BRGH = 0)

BAUD RATE	FCY = 16 MHz			FCY = 12 MHz		
	Actual Baud Rate	% Error	BRG Value (Decimal)	Actual Baud Rate	% Error	BRG Value (Decimal)
110	110.0	0.00	9090	110.0	0.00	6817
300	300.0	0.01	3332	300.0	0.00	2499
1200	1200.5	0.04	832	1200.0	0.00	624
2400	2398.1	-0.08	416	2403.8	0.16	311
9600	9615.4	0.16	103	9615.3	0.16	77
19.2K	19230.8	0.16	51	19230.7	0.15	38
38.4K	38461.5	0.16	25	37500.0	-2.34	19
56K	55555.6	-0.79	17	57692.3	-3.02	12
115K	111111.1	-3.38	8			
250K	250000.0	0.00	3			
300K						
500K	500000.0	0.00	1			
Min.	15.0	0.00	65535	11.0	0.00	65535
Max.	1000000.0	0.00	0	480000.0	0.00	0

BAUD RATE	FCY = 8 MHz			FCY = 4 MHz			FCY = 1 MHz		
	Actual Baud Rate	% Error	BRG Value (Decimal)	Actual Baud Rate	% Error	BRG Value (Decimal)	Actual Baud Rate	% Error	BRG Value (Decimal)
110	917.4	0.00	4544	110.0	0.00	2272	110.0	0.00	567
300	299.9	0.00	1666	300.1	0.00	832	300.4	0.10	207
1200	1199.0	0.00	416	1201.9	0.16	207	1201.9	0.16	51
2400	2403.8	0.16	207	2403.8	0.15	103	2403.8	0.15	25
9600	9615.4	0.16	51	9615.4	0.20	25			
19.2K	19230.8	0.16	25	19230.8	0.20	12			
38.4K	38461.5	0.16	12						
56K	55555.6	-0.79	8						

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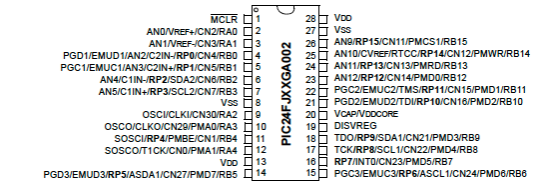
UART Pin Mapping – Reprogrammable Pin Mapping

- UART Baud Rate Configuration
  - *Q: Where's the TX and RX pins on the PIC24F?*

28-Pin SPDIP, SSOP, SOIC



  - *A: No Dedicated Pins.*
    - Instead, any *RP* pin can be utilized

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UART Pin Mapping – Reprogrammable Pin Mapping

- Peripheral Pin Selection (i.e. reprogrammable pin mapping)
  - Input Mapping: Maps specific RP input pins to peripheral inputs
    - RPINRx: Input mapping for peripheral input to RPx pin
      - Must consult datasheet to determine RPINRx register and bits needed to specific pin peripheral
      - Value assigned to bits within RPINRx register correspond to PRx pin number

TABLE 10-2: SELECTABLE INPUT SOURCES (MAPS INPUT TO FUNCTION)(1)

Input Name	Function Name	Register	Configuration Bits
External Interrupt 1	INT1	RPINR0	INTR1<4:0>
External Interrupt 2	INT2	RPINR1	INTR2R<4:0>
Timer2 External Clock	T2CK	RPINR3	T2CKR<4:0>
Timer3 External Clock	T3CK	RPINR3	T3CKR<4:0>
Timer4 External Clock	T4CK	RPINR4	T4CKR<4:0>
Timer5 External Clock	T5CK	RPINR4	T5CKR<4:0>
Input Capture 1	IC1	RPINR7	IC1R<4:0>
Input Capture 2	IC2	RPINR7	IC2R<4:0>
Input Capture 3	IC3	RPINR8	IC3R<4:0>
Input Capture 4	IC4	RPINR8	IC4R<4:0>
Input Capture 5	IC5	RPINR9	IC5R<4:0>
Output Compare Fault A	OCFA	RPINR11	OCFAR<4:0>
Output Compare Fault B	OCFB	RPINR11	OCFBR<4:0>
UART1 Receive	U1RX	RPINR18	U1RXR<4:0>
UART1 Clear To Send	$\overline{U1CTS}$	RPINR18	U1CTSR<4:0>
UART2 Receive	U2RX	RPINR19	U2RXR<4:0>
UART2 Clear To Send	$\overline{U2CTS}$	RPINR19	U2CTSR<4:0>
SPI1 Data Input	SDI1	RPINR20	SDI1R<4:0>
SPI1 Clock Input	SCK1IN	RPINR20	SCK1R<4:0>
SPI1 Slave Select Input	SS1IN	RPINR21	SS1R<4:0>
SPI2 Data Input	SDI2	RPINR22	SDI2R<4:0>
SPI2 Clock Input	SCK2IN	RPINR22	SCK2R<4:0>
SPI2 Slave Select Input	SS2IN	RPINR23	SS2R<4:0>

```
RPINR18bits.U1RXR = 9;
```

register for UART1

bits for UART1 RX input

assigned to RP9

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UART Pin Mapping – Reprogrammable Pin Mapping

- Peripheral Pin Selection (i.e. reprogrammable pin mapping)
  - Output Mapping: Maps specific peripheral outputs to RP pins
    - RPORx: Output mapping for peripherals outputs from specific peripheral inputs
      - Must consult datasheet to determine RPORx register for specific RPy outputs
      - Two RPy outputs are mapped to 4-bits within each RPOPx register
      - Value assigned to bits within RPORx correspond to specific peripheral outputs

Function	Output Function Number(1)	Output Name
NULL(2)	0	NULL
C1OUT	1	Comparator 1 Output
C2OUT	2	Comparator 2 Output
U1TX	3	UART1 Transmit
$\overline{U1RTS}$(3)	4	UART1 Request To Send
U2TX	5	UART2 Transmit
$\overline{U2RTS}$(3)	6	UART2 Request To Send
SDO1	7	SPI1 Data Output
SCK1OUT	8	SPI1 Clock Output
SS1OUT	9	SPI1 Slave Select Output
SDO2	10	SPI2 Data Output
SCK2OUT	11	SPI2 Clock Output
SS2OUT	12	SPI2 Slave Select Output
OC1	18	Output Compare 1
OC2	19	Output Compare 2
OC3	20	Output Compare 3
OC4	21	Output Compare 4
OC5	22	Output Compare 5

```
RPOR4bits.RP8R = 3;
```

register for RP8 and RP9 outputs

bits for RP8 output

assigned to UART1 TX