FPSLIC Baud Rate Generator

Features:

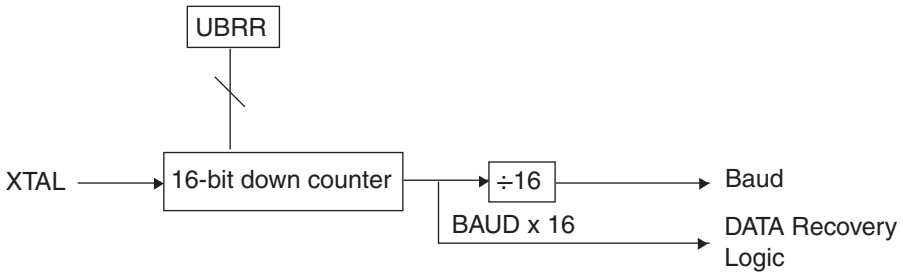
- **Generates any required baud rate**
- **High baud rates at low crystal clock frequencies**
- **Uses both internal and external clock sources**
- **Supports in both single speed and double speed modes**
- **Easy-to-use "Excel" table to calculate any baud rate**

Description:

The baud rate generator provides both the receiver and the transmitter with the baud rate clock, a bit-period clock.

Each generator consists of a 16-bit time constant register and a 16-bit down counter. In operation, the counter decrements with each baud rate generator clock, with the time constant automatically reloaded when the count reaches zero. The output of the baud rate generator toggles when the counter reaches a count of one-half of the time constant, and it toggles again when the counter reaches zero. A new time constant may be written at any time, but the new value will not take effect until the next load of the counter. The baud rate generator output frequency is shown on the following section.

Figure 1. Block Diagram of Baud Rate Generator



FPSLIC™

AT94K Series Field Programmable System Level Integrated Circuit

Application Note

Rev. 2284A–04/01

The Baud Rate Generator in Single UART Speed Mode

The baud rate generator is a frequency divider that generates baud rates according to the following equation:

Figure 2. Baud Rate Equation at Double Speed

$$BAUD = \frac{f_{CK}}{16(UBR + 1)}$$

Notes:
1. BAUD = Baud rate
2. f CK = Crystal Clock frequency
3. UBR = Contents of the UBRRH and UBRR registers, (0-4095)
4. This equation is not valid when the UART transmission speed is doubled. See Table 2 on page 4 for a detailed description.

The most commonly used baud rates for standard crystal frequencies can be generated by using the UBR settings in Table 1. UBR values that yield an actual baud rate differing less than 2% from the target baud rate appear in bold. However, it is not recommended to use baud rates that have more than 1% error. High error ratings give less noise resistance.

Table 1. UBR Settings at Various Crystal Frequencies

Baud Rate	1 MHz		% Error	1.8432 MHz		% Error	2 MHz		% Error
2400	UBR=	**25**	**0.2**	UBR=	**47**	**0.0**	UBR=	**51**	**0.2**
4800	UBR=	**12**	**0.2**	UBR=	**23**	**0.0**	UBR=	**25**	**0.2**
9600	UBR=	6	7.5	UBR=	**11**	**0.0**	UBR=	**12**	**0.2**
14400	UBR=	3	7.8	UBR=	**7**	**0.0**	UBR=	8	3.7
19200	UBR=	2	7.8	UBR=	**5**	**0.0**	UBR=	6	7.5
28800	UBR=	1	7.8	UBR=	**3**	**0.0**	UBR=	3	7.8
38400	UBR=	1	22.9	UBR=	**2**	**0.0**	UBR=	2	7.8
57600	UBR=	0	7.8	UBR=	**1**	**0.0**	UBR=	1	7.8
76800	UBR=	0	22.9	UBR=	1	33.3	UBR=	1	22.9
115200	UBR=	0	84.3	UBR=	**0**	**0.0**	UBR=	0	7.8

Baud Rate	3.2768 MHz		% Error	3.6864 MHz		% Error	4 MHz		% Error
2400	UBR=	**84**	**0.4**	UBR=	**95**	**0.0**	UBR=	**103**	**0.2**
4800	UBR=	**42**	**0.8**	UBR=	**47**	**0.0**	UBR=	**51**	**0.2**
9600	UBR=	**20**	**1.6**	UBR=	**23**	**0.0**	UBR=	**25**	**0.2**
14400	UBR=	**13**	**1.6**	UBR=	**15**	**0.0**	UBR=	16	2.1
19200	UBR=	10	3.1	UBR=	**11**	**0.0**	UBR=	**12**	**0.2**
28800	UBR=	**6**	**1.6**	UBR=	**7**	**0.0**	UBR=	8	3.7
38400	UBR=	4	6.3	UBR=	**5**	**0.0**	UBR=	6	7.5
57600	UBR=	3	12.5	UBR=	**3**	**0.0**	UBR=	3	7.8
76800	UBR=	2	12.5	UBR=	**2**	**0.0**	UBR=	2	7.8
115200	UBR=	1	12.5	UBR=	**1**	**0.0**	UBR=	1	7.8

Baud Rate	7.3728 MHz		% Error	8 MHz		% Error	9.216 MHz		% Error
2400	UBR=	**191**	**0.0**	UBR=	**207**	**0.2**	UBR=	**239**	**0.0**
4800	UBR=	**95**	**0.0**	UBR=	**103**	**0.2**	UBR=	**119**	**0.0**
9600	UBR=	**47**	**0.0**	UBR=	**51**	**0.2**	UBR=	**59**	**0.0**
14400	UBR=	**31**	**0.0**	UBR=	**34**	**0.8**	UBR=	**39**	**0.0**
19200	UBR=	**23**	**0.0**	UBR=	**25**	**0.2**	UBR=	**29**	**0.0**
28800	UBR=	**15**	**0.0**	UBR=	16	2.1	UBR=	**19**	**0.0**
38400	UBR=	**11**	**0.0**	UBR=	**12**	**0.2**	UBR=	**14**	**0.0**
57600	UBR=	**7**	**0.0**	UBR=	8	3.7	UBR=	**9**	**0.0**
76800	UBR=	**5**	**0.0**	UBR=	6	7.5	UBR=	7	6.7
115200	UBR=	**3**	**0.0**	UBR=	3	7.8	UBR=	**4**	**0.0**

UART0 and UART1 High byte Baud Rate Register UBRRHI

Bit	7	6	5	4	3	2	1	0
$20 ($40)	MSB1			LSB1	MSB0			LSB0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Initial Value	0	0	0	0	0	0	0	0

The UART baud register is a 12-bit register. The 4 most significant bits are located in a separate register, UBRRHI. Note that both UART0 and UART1 share this register. Bit 7 to bit 4 of UBRRHI contain the 4 most significant bits of the UART1 baud register. Bit 3 to Bit 0 contain the 4 most significant bits of the UART0 baud register.

UART0 Baud Rate Register Low byte - UBRR0

Bit	7	6	5	4	3	2	1	0
$09 ($29)	MSB							LSB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Initial Value	0	0	0	0	0	0	0	0

UART1 Baud Rate Register Low byte - UBRR1

Bit	7	6	5	4	3	2	1	0
$00 ($20)	MSB							LSB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Initial Value	0	0	0	0	0	0	0	0

The Baud Rate Generator in Double UART Speed Mode

Note that the baud rate equation is different from the equation on Figure 2 on page 2 when the UART speed is doubled.

Figure 3. Baud Rate Equation

$$BAUD = \frac{f_{CK}}{8(UBR + 1)}$$

Notes:
1. BAUD = Baud rate
2. f CK = Crystal Clock frequency
3. UBR = Contents of the UBRRHI and UBRR registers, (0-4095)
4. This equation is only valid when the UART transmission speed is doubled. See Table 2 on page 4 for a detailed description.

The most commonly used baud rates for standard crystal frequencies can be generated by using the UBR settings in Table 2 on page 4. UBR values that yield an actual baud rate differing less than 1.5% from the target baud rate are bold in the table. However since the number of samples are reduced and the system clock might have some variance (this applies especially when using resonators), it is recommended that the baud rate error is less than 0.5%.

Table 2. UBR Settings at Various Crystal Frequencies in Double Speed Mode

Baud Rate	1.0000 MHz	% Error	1.8432 MHz	% Error	2.0000 MHz	% Error
2400	UBR = **51**	**0.2**	UBR = **95**	**0.0**	UBR = **103**	**0.2**
4800	UBR = **25**	**0.2**	UBR = **47**	**0.0**	UBR = **51**	**0.2**
9600	UBR = **12**	**0.2**	UBR = **23**	**0.0**	UBR = **25**	**0.2**
14400	UBR = 8	3.7	UBR = **15**	**0.0**	UBR = 16	2.1
19200	UBR = 6	7.5	UBR = **11**	**0.0**	UBR = **12**	**0.2**
28800	UBR = 3	7.8	UBR = **7**	**0.0**	UBR = 8	3.7
38400	UBR = 2	7.8	UBR = **5**	**0.0**	UBR = 6	7.5
57600	UBR = 1	7.8	UBR = **3**	**0.0**	UBR = 3	7.8
76800	UBR = 1	22.9	UBR = **2**	**0.0**	UBR = 2	7.8
115200	UBR = 0	84.3	UBR = **1**	**0.0**	UBR = 1	7.8
230400	-	-	UBR = **0**	**0.0**	UBR = 0	84.3
Baud Rate	3.2768 MHz	% Error	3.6864 MHz	% Error	4.0000 MHz	% Error
2400	UBR = **170**	**0.2**	UBR = **191**	**0.0**	UBR = **207**	**0.2**
4800	UBR = **84**	**0.4**	UBR = **95**	**0.0**	UBR = **103**	**0.2**
9600	UBR = **42**	**0.8**	UBR = **47**	**0.0**	UBR = **51**	**0.2**
14400	UBR = 27	1.6	UBR = **31**	**0.0**	UBR = **34**	**0.8**
19200	UBR = 20	1.6	UBR = **23**	**0.0**	UBR = **25**	**0.2**
28800	UBR = 13	1.6	UBR = **15**	**0.0**	UBR = 16	2.1
38400	UBR = 10	3.1	UBR = **11**	**0.0**	UBR = **12**	**0.2**
57600	UBR = 6	1.6	UBR = **7**	**0.0**	UBR = 8	3.7
76800	UBR = 4	6.2	UBR = **5**	**0.0**	UBR = 6	7.5
115200	UBR = 3	12.5	UBR = **3**	**0.0**	UBR = 3	7.8
230400	UBR = 1	12.5	UBR = **1**	**0.0**	UBR = 1	7.8
460800	UBR = 0	12.5	UBR = **0**	**0.0**	UBR = 0	7.8
912600	-	-	-	-	UBR = 0	84.3
Baud Rate	7.3728 MHz	% Error	8.0000 MHz	% Error	9.2160 MHz	% Error
2400	UBR = **383**	**0.0**	UBR = **416**	**0.1**	UBR = **479**	**0.0**
4800	UBR = **191**	**0.0**	UBR = **207**	**0.2**	UBR = **239**	**0.0**
9600	UBR = **95**	**0.0**	UBR = **103**	**0.2**	UBR = **119**	**0.0**
14400	UBR = **63**	**0.0**	UBR = **68**	**0.6**	UBR = **79**	**0.0**
19200	UBR = **47**	**0.0**	UBR = **51**	**0.2**	UBR = **59**	**0.0**
28800	UBR = **31**	**0.0**	UBR = **34**	**0.8**	UBR = **39**	**0.0**
38400	UBR = **23**	**0.0**	UBR = **25**	**0.2**	UBR = **29**	**0.0**
57600	UBR = **15**	**0.0**	UBR = 16	2.1	UBR = **19**	**0.0**
76800	UBR = **11**	**0.0**	UBR = 12	**0.2**	UBR = **14**	**0.0**
115200	UBR = **7**	**0.0**	UBR = 8	3.7	UBR = **9**	**0.0**
230400	UBR = **3**	**0.0**	UBR = 3	7.8	UBR = **4**	**0.0**
460800	UBR = **1**	**0.0**	UBR = 1	7.8	UBR = 2	20.0
912600	UBR = **0**	**0.0**	UBR = 0	7.8	UBR = 0	20.0

Calculating your own Baud Rate

Following is a sample Excel table used to calculate the different baud rate. Each cell's equation is shown below:

	A	B	C	D	E	F	G	H
1	Clock MHz	UBRRHI 7:4 or 3:0	UBRRn	UBR HEX	UBR	Actual Freq	Desired Freq.	% Error
2	1	**0000**	**00011001**	**019**	**25**	**2404**	**2400**	**0.2**
3		**0000**	**00001100**	**00C**	**12**	**4808**	**4800**	**0.2**
4		0000	00000110	006	6	8929	9600	7.5
5		0000	00000011	003	3	15625	14400	7.8
6		0000	00000010	002	2	20833	19200	7.8
7		0000	00000001	001	1	31250	28880	7.6
8		0000	00000001	001	1	31250	38400	22.9
9		0000	00000000	000	0	62500	57600	7.8
10		0000	00000000	000	0	62500	76800	22.9
11		0000	00000000	000	0	62500	115200	84.3

```
UBRRHI      = DEC2BIN((E2/256),4)
UBRRn       = DEC2BIN(MOD(E2, 256), 8)
UBR HEX     = DEC2HEX(E2, 3)
Actual Freq= (clock1 (1) 1000000)/((1+E2)*16)
% Error     = ABS(((G2-F2)/F2)(1)-100)
```

Note: 1. Some of the functions don't come as default when you first install your Excel. Please go to **Tools** >> **Add-Ins** to install the required library. The baud rate excel sheet can be found under C:\SystemDesigner\examples\at94k\resources\baudrate.xls

Brief C example on how to set UBRRHI and UBRRn

```
int UBR = 25;/* Set UBR value */

UBRRHI |= (((UBR) >> 8) & 0x000F ); /* Calculate UBRRHI from 3 down to 0 */
UBRR0 |= ((UBR) & 0x00FF);   /* Calculate UBRR0 */

UBRRHI |= (((UBR) >> 4) & 0x00F0 );/* Calculate UBRRHI from 7 down to 4 */
UBRR1 |= ((UBR) & 0x00FF);/* Calculate UBRR1 */
```

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