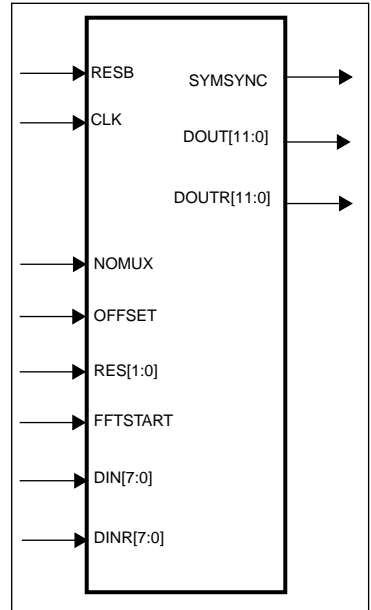## *Advance Information*
2K - Samples FFT-Processor

The MC92307 is a pipelined Fast Fourier Transformation (FFT) processor with a blocklength of 2048 complex samples. It is especially designed for use in digital terrestrial Set-Top boxes according to the DVB-T standard for 2K transmission. One block of 2048 complex samples can be processed in 224 μs

Feature Summary

- Processing of one block of 2048 complex samples (i.e. one 2K-OFDM symbol) in 224 μs.
- Designed for direct interfacing with Motorola's OFDM demodulator MC92308.
- Input wordlength 8 bit, output accuracy selectable between 10 and 12 bit.
- Overflow on certain OFDM subcarriers due to co-channel interferes is handled internally.
- Readout of output samples can be shifted by half the blocklength to start at the middle of the output block.
- Either multiplexed or non-multiplexed input and output format (the multiplexed mode allows direct interfacing with Motorola's OFDM Demodulator MC92308).
- Internal Bit reversal can be disabled to allow the construction of FFT modules for blocklengths > 2K by using several devices in parallel.
- Low clock rate inputs and outputs.
- 0.5μm CMOS process at 3.3 V.
- 5 V tolerant inputs and outputs.

	RESB	SYMSYNC	
	CLK	DOUT[11:0]	
		DOUTR[11:0]	
	NOMUX		
	OFFSET		
	RES[1:0]		
	FFTSTART		
	DIN[7:0]		
	DINR[7:0]		

Ordering Information

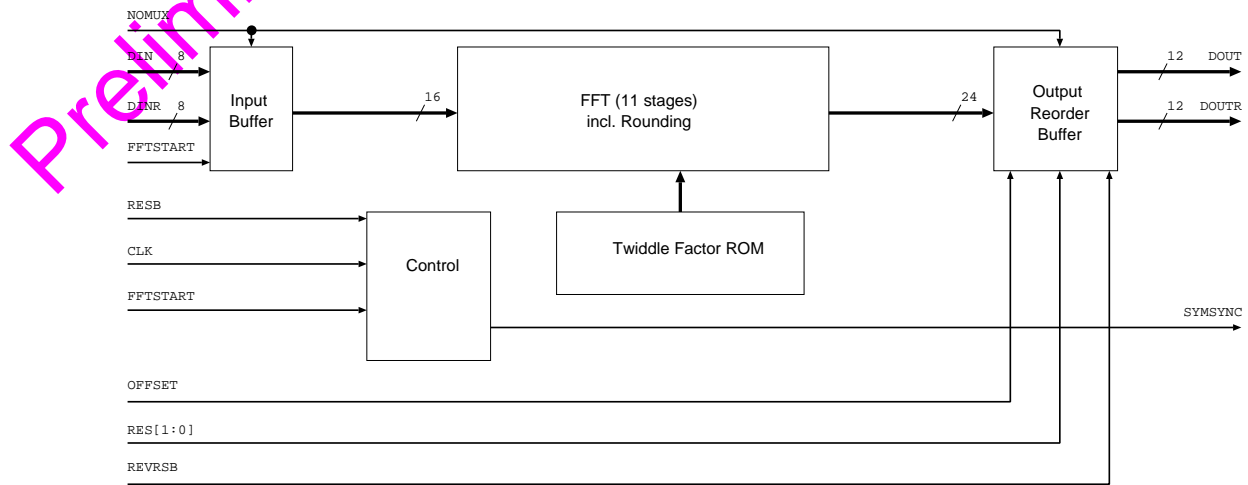| Device	Package
MC92307CI	160QFP

Figure 1. Block diagram of the FFT processor MC92307

This document contains information on a new product.
Specifications and information herein are subject to change without notice.

Fast Fourier Transform in the DVB-T System

Within the DVB consortium several standards for digital television broadcast were submitted for the different transmission media, leading to DVB-S (satellite), DVB-C (cable) and DVB-T (terrestrial). The details of the DVB-T system are described in reference [1]. To cope with the special effects of digital <u>terrestrial</u> transmission the OFDM modulation scheme was chosen: In principle the whole available bandwidth is divided into a large number N (e.g. 2048) of separate narrowband subchannels (the OFDM subcarriers). Data associated with each subcarrier are transmitted independently from and in parallel with the other subcarriers, leading to a very low datarate on each subcarrier compared to the overall transmission capacity.

The superposition of all the subcarriers in the transmitter is achieved very efficiently by an IFFT. Consequently the corresponding functional block in the receiver is a FFT. This IFFT -> FFT pair is one of the central elements in all OFDM systems, it represents the link between the so-called frequency domain and the time domain used for the RF link between the transmitter and the receiver. Therefore one of the important parameters describing an OFDM system is the blocklength of the IFFT/FFT, such a block is called an 'OFDM symbol'.

In the DVB-T specification two modes are described, the first with 2048 (2K) complex samples per OFDM symbol, the second with 8192 (8K) samples per block. The MC92307 device described here is designed especially for the use in systems working according in the 2K-mode described in reference [1].

External Interfaces

Control Interface

CLK

The overall OFDM transmission clock of app. 36.57 MHz must be provided at this pin. Obviously in case of a DVB-T frontend composed of a MC92308 together with the MC92307 both devices have to be supplied with the same clock signal. Normally the 36.57 MHz are generated by a VCXO in the tuner which in turn is controlled by the OFDM timing synchronization circuitry.

RESB

Synchronous Reset: Normally H, a L together with a rising edge at CLK puts all outputs in tri-state and aborts any processing, leaving the FFT device in the idle mode.

OFFSET

After the completion of the FFT processing the frequency domain data are output by the reorder buffer, starting together with a pulse of the SYMSYNC pin. The starting position of the output can be selected with the OFFSET pin. With OFFSET set to L the first frequency domain sample of a block that is delivered at the output of the FFT device belongs the baseband frequency corresponding to the DC component (i.e. the center frequency in the received time domain signal). The numbers of the frequency bins increases continuously until bin #2047 at the end of the block.

If OFFSET is set to H the first frequency domain sample belongs to the baseband frequency bin #1024, corresponding to an offset of one half of the block (i.e. the DC component in the received time domain signal). Again the bin numbers increase up to bin #2047. Then a wraparound to bin #0 occurs.

Table 1. Function of OFFSET

Sample # after SYMSYNC	(Baseband) Bin # (OFFSET = L)	(Baseband) Bin # (OFFSET = H)
s_0	$DOUT_0$	$DOUT_{1024}$
s_1	$DOUT_1$	$DOUT_{1025}$
...	...	...
s_{1022}	$DOUT_{1022}$	$DOUT_{2046}$
sd_{1023}	$DOUT_{1023}$	$DOUT_{2047}$
s_{1024}	$DOUT_{1024}$	$DOUT_0$
...	...	...
s_{2046}	$DOUT_{2046}$	$DOUT_{1022}$
s_{2047}	$DOUT_{2047}$	$DOUT_{1023}$

Note that the bin numbers given in the table above correspond to the **baseband** positions.

NOMUX

The input interface (DIN and DINR) and the output interface (DOUT and DOUTR) can be used in two modes:

Normally the complex samples are provided in the MULTIPLEXED mode, i.e. at first the real part of one sample is transferred using the DIN or DOUT lines followed by the imaginary part of the same sample using the same physical pins. The pins labelled DINR and DOUTR pins are not used, DINR should be tied to a fixed value and DOUTR should be left unconnected. The multiplexed mode is selected by setting the NOMUX line at L level, note that it is the only mode the FFT device MC92307 can be used together with the OFDM device MC92308.

If NOMUX is set to H the real and imaginary part of one sample is transferred in parallel using the DINR and DOUTR lines for the real part and the DIN and DOUT lines for the imaginary part. Consequently the transfer rate is divided by 2 compared to the muxed mode at the cost of more interconnection lines. Therefore this mode is intended mainly for use with external devices that operate on lower rates.

REVRSB

To achieve the output of the frequency domain data in natural order an internal bit reversal is done in the output reorder buffer. This bit reversal can be switched off e.g. to allow the combination of 4 MC92307 devices together with an external final radix-4 butterfly stage to do an 8K-FFT.

RES[1:0]

These two lines support the selection of the wordlength at the FFT output:

Table 2. Output resolution selection

RES[1:0]	DOUT[11:0]
00	$[0, 0, d_9, d_8, ... , d_0,]$
01	$[0, d_{10}, d_9, d_8, ... , d_0,]$
10	$[d_{11}, d_{10}, d_9, d_8, ... , d_0,]$
11	Don't care

OFDM Device -> FFT Device

The figures below illustrate the input of the time domain data into the FFT device and the output of the calculated frequency domain data after the completion of the FFT. The samples belonging to the real part are denoted by ...r (real), the imaginary samples are marked with ...q (quadrature). Figure 2 applies for the Multiplexed mode, Figure 3 is valid for the Non-multiplexed mode.
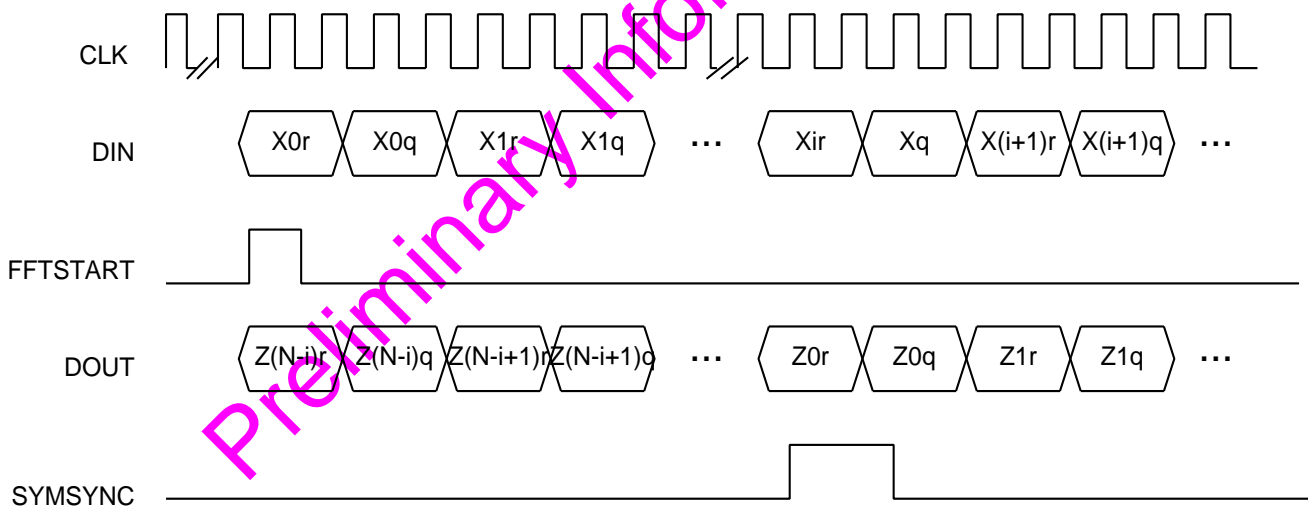

Figure 2. FFT Data I/O for the Multiplexed Mode
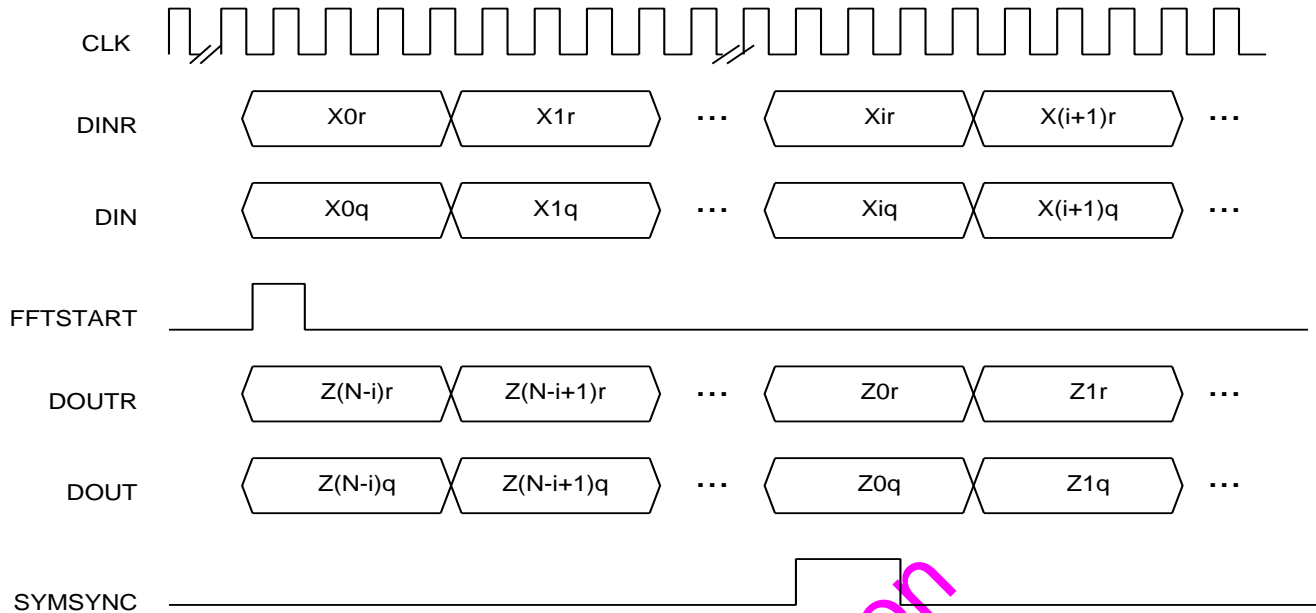
External Interfaces

Figure 3. Data I/O for the Non-multiplexed Mode

FFTSTART

The input of a data block into the FFT device starts with a pulse of the FFTSTART signal. It must be delivered together with the real part of the first time domain sample and should last 1..2 clock cycles.

DIN [7:0]

These pins accept the input data with a wordlength of 8 bit. In the muxed mode first the real part of a sample must be provided followed by the imaginary part. In the non-muxed mode only the imaginary part must be delivered to DIN. The data format is fixed to 2's complement.

DINR [7:0]

In the non-muxed mode (NOMUX = H) the real part of the input samples is entered into the FFT device via these pins (they should be connected to a fixed level if the muxed mode is used). As the DIN inputs these inputs expect 2's complement format.

FFT Device -> OFDM Device

SYMSYNC

The start of the output of a FFT block after processing is indicated by a pulse of the SYMSYNC signal with a duration of 2 clock cycles. It is delivered together with the real part of the first output sample.

DOUT [11:0]

These pins deliver the output data of the FFT device in 2's complement format. In the non-muxed mode (NOMUX = H) the real part of the samples is followed by the imaginary part. In the muxed mode only the imaginary parts appears at the DOUT pins. The valid bits are adjusted using the RES pins, see above.

DOUTR [11:0]

In the non-muxed mode (NOMUX = H) the real part of the output samples appears at these pins in 2's complement format. The wordlength selection by the RES pins is also valid for DOUTR. If the non-muxed mode is used these pins may be left unconnected.
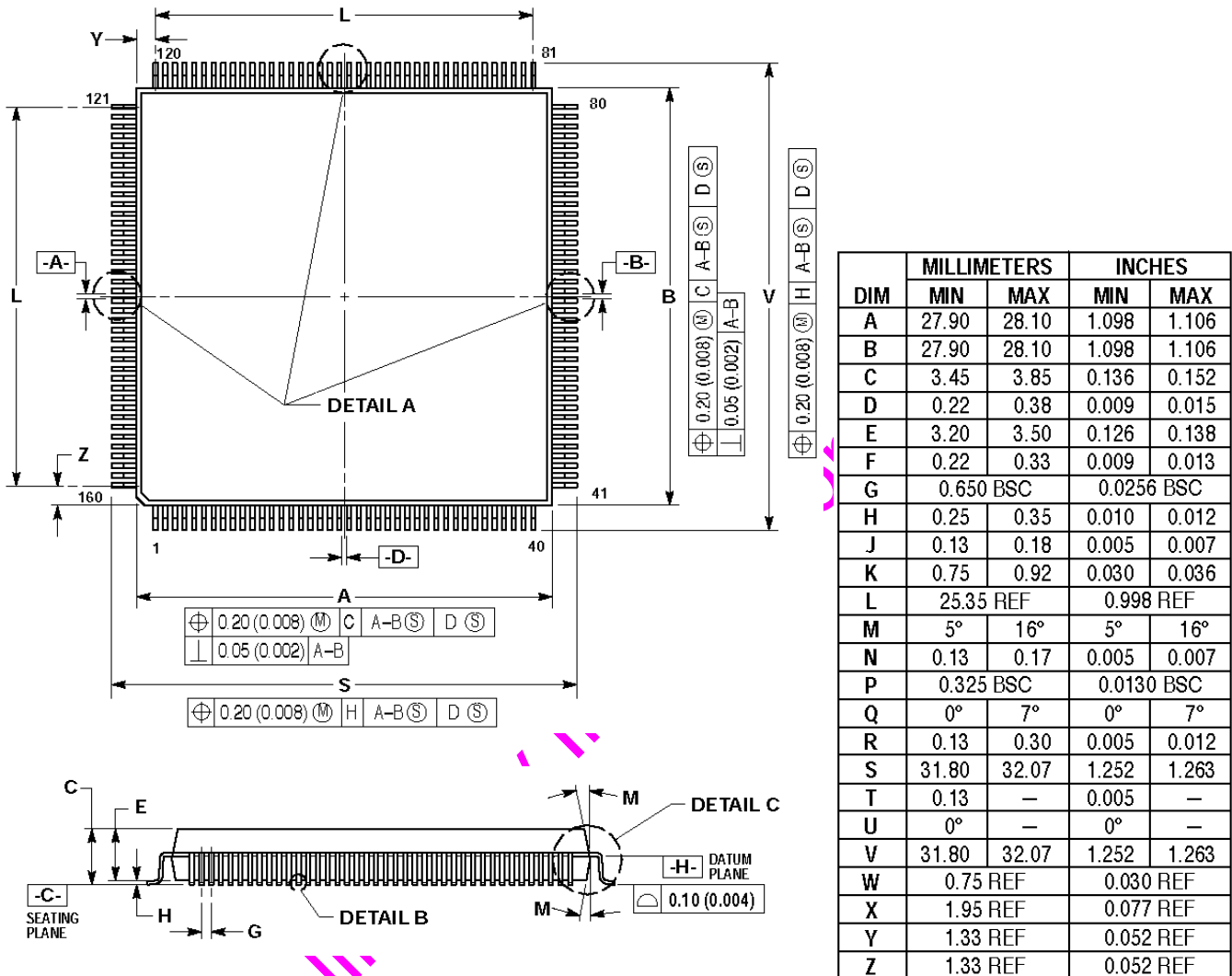
Pinout

Motorola's FFT device is packaged into a 160QFP package. The pinout of this package as well as the input and output lines are given in Figure 4 and Table 3.

The supply voltage of the IC is 3.3 V, its power consumption will be app. 0.75 W in a typical DVB-T application as it is described in "Application Information".

Figure 4. Pinout of the MC92307

Table 3. MC92307 Pin Description of the FFT device

SIGNAL	FUNCTIONALITY
RESB	Synchronous Reset (active low)
CLK	36.57 MHz clock
REVRSB	Enable bit reversal (active low)
DIN[7:0]	Complex data input muxed (real component first)
RES[1:0]	Output resolution selection
OFFSET	Selection of half symbol rotation in output
FFTSTART	Input frame start
DOUT[11:0]	Complex data output muxed (real component first)
SYMSYNC	Output frame start
NOMUX	Selection of non-multiplexed data busses
DINR[7:0]	Complex data input (real part) if NOMUX = 1
DOUTR[11:0]	Complex data output (real part) if NOMUX = 1

Package Data

The mechanical dimensions of the 160QFP package
that is used for the FFT device are shown below:

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	27.90	28.10	1.098	1.106
B	27.90	28.10	1.098	1.106
C	3.45	3.85	0.136	0.152
D	0.22	0.38	0.009	0.015
E	3.20	3.50	0.126	0.138
F	0.22	0.33	0.009	0.013
G	0.650 BSC		0.0256 BSC	
H	0.25	0.35	0.010	0.012
J	0.13	0.18	0.005	0.007
K	0.75	0.92	0.030	0.036
L	25.35 REF		0.998 REF	
M	5°	16°	5°	16°
N	0.13	0.17	0.005	0.007
P	0.325 BSC		0.0130 BSC	
Q	0°	7°	0°	7°
R	0.13	0.30	0.005	0.012
S	31.80	32.07	1.252	1.263
T	0.13	—	0.005	—
U	0°	—	0°	—
V	31.80	32.07	1.252	1.263
W	0.75 REF		0.030 REF	
X	1.95 REF		0.077 REF	
Y	1.33 REF		0.052 REF	
Z	1.33 REF		0.052 REF	

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DATUM PLANE -H- IS LOCATED AT BOTTOM OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE BOTTOM OF THE PARTING LINE.
4. DATUMS -A-, –B- AND -D- TO BE DETERMINED AT DATUM PLANE -H-.
5. DIMENSIONS S AND V TO BE DETERMINED AT SEATING PLANE -C-.
6. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 (0.010) PER SIDE. DIMENSIONS A AND B DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -H-.
7. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT.

Figure 5. Mechanical Data of the 160QFP Package

Application Information

As already mentioned the FFT device is especially suited to be combined with Motorola's OFDM device MC92308 to form the complete digital part of a frontend for a 2K DVB-T receiver. Refer to Figure 6 for the functional blocks of a terrestrial DVB receiver. Further details of the blocks are given in reference [2].

One of the key signals for the successful reception of an OFDM signal is the correct timing synchronization, that means that the synchronization circuitry chooses the correct starting point to trigger the FFT operation. Therefore the OFDM demodulator MC92308 provides the FFTSTART signal to the FFT device. If 2048 complex time domain samples have been read into the input buffer the FFT operation starts. Its result is flagged with the SYMSYNC line and the calculated frequency domain samples are output to the OFDM device that continues with the demodulation process.
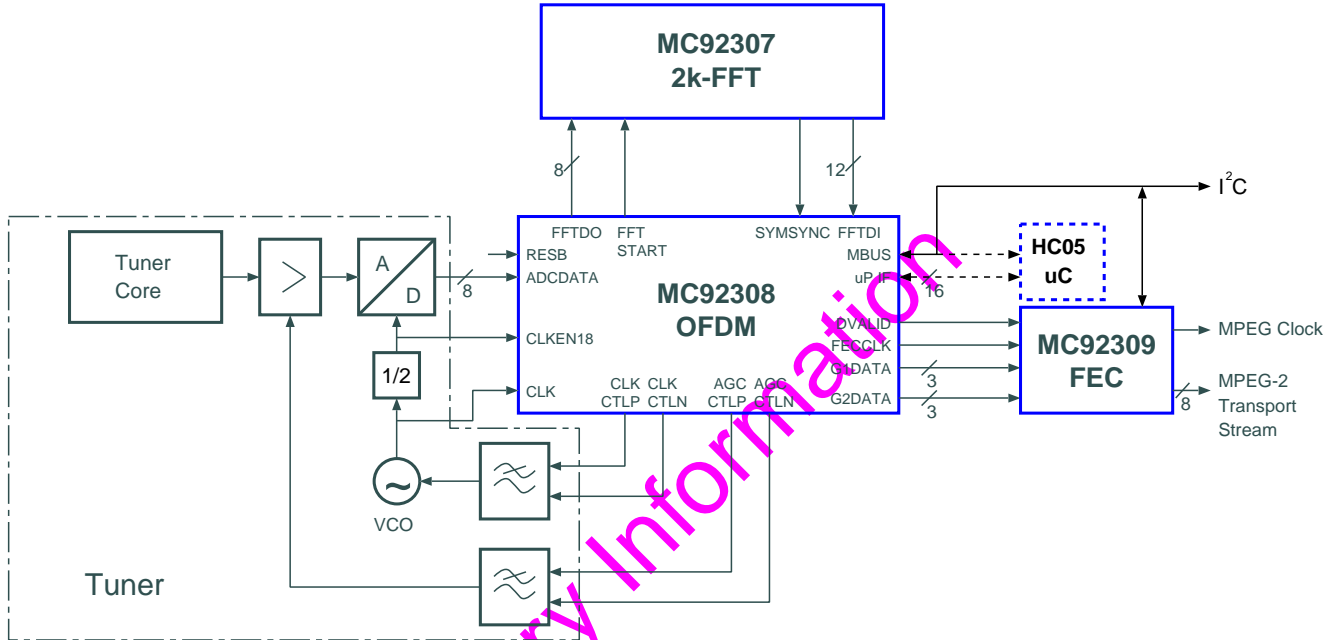
Figure 6. Application Example for the OFDM and FFT Devices

Switching Characteristics

In the following diagram together with the associated table the characteristics of the interface for the FFT data is given. Note that they are valid for temperatures between 0°C and 80°C and a supply voltage range of 3.0 V - 3.6 V
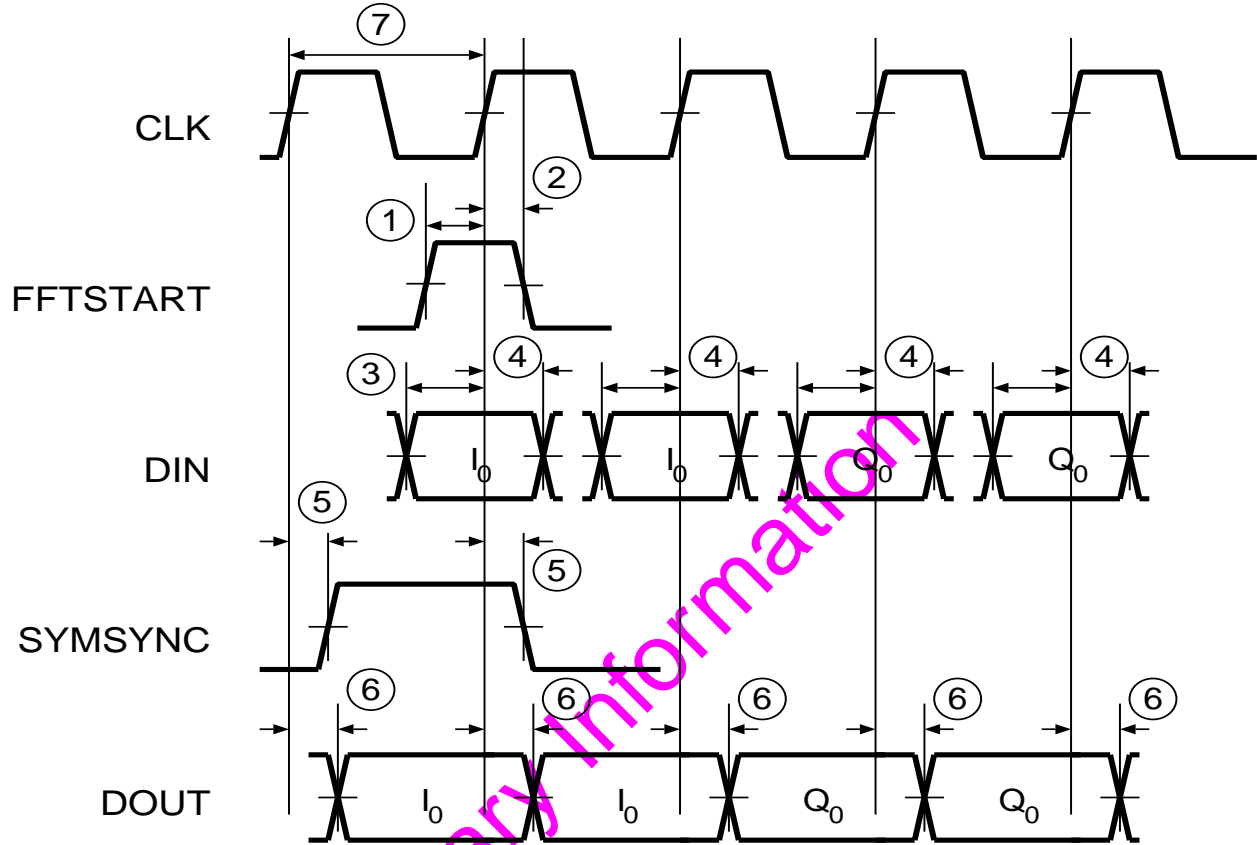
Figure 7. Timing Characteristic of the FFT Device

Table 4. Timing Data for the FFT Device

No.	Characteristic	min	max	unit
1	FFTSTART to CLK setup time		1.4	ns
2	FFTSTART to CLK hold time		3.1	ns
3	Data in to CLK setup time		2.3	ns
4	Data in to CLK hold time		3.5	ns
5	CLK to SYMSYNC out delay	4.6	13.1	ns
6	CLK to Data out delay	3.6	11.8	ns
7	CLK period	27.4		ns

References

[1] Digital broadcasting systems for television, sound and data services; Framing structure, channel coding and modulation for digital terrestrial television. Draft prETS 300 744 published by ETSI September 1996.

[2] MC92308 OFDM Demodulator, Product Data Sheet for the MC92308.

MOTOROLA

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