

Additional Resources	Filter coefficients used in this Application Note can be downloaded from the CMX983 product page on the CML website.
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1 Introduction

This Application Note discusses the suitability and use of a set of CMX983 filter coefficients to implement DMR receiver channel filtering.

2 History

Version	Changes	Date
1	First release	21/11/14

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4 The DMR Channel filter

The CMX983 Baseband Interface chip is suitable for use in a DMR receiver for analogue-to-digital conversion and channel filtering. In this application it is essential that the channel filter is flat across the pass-band and provides sufficient stop-band attenuation to achieve sufficient adjacent channel rejection in accordance with ETSI EN 300 113-1, the RF performance standard applicable to the DMR system as defined in ETSI TS 102 361.

4.1 An Example Filter

Figure 1 shows the magnitude spectrum of a linear phase FIR filter for DMR applications that has been designed by CML Microcircuits. The filter has been designed to operate at a channel sampling rate of 48 kHz after the first down-sampler in the CMX983.

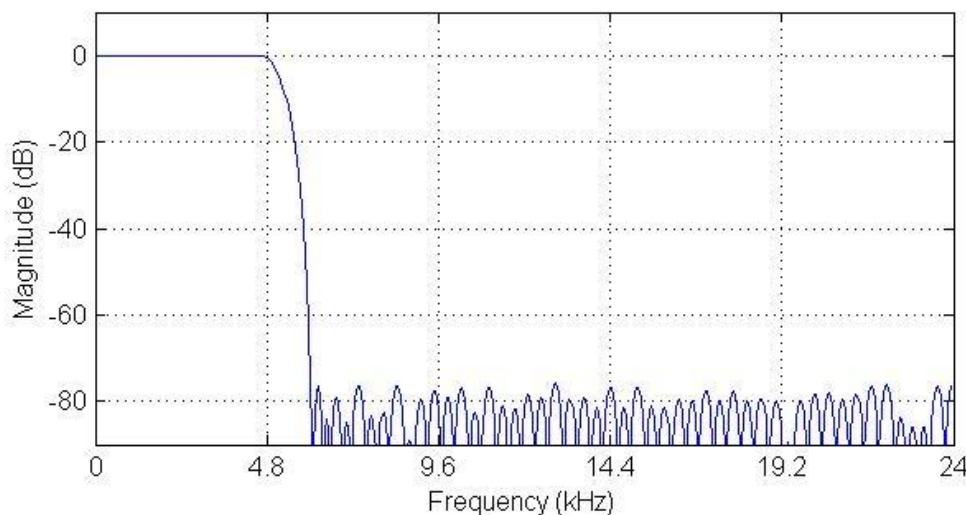


Figure 1 – Channel filter magnitude spectrum

The coefficients used in this 127 tap filter are provided at the end of this Application Note as both 16-bit signed integers, for use with the CMX983 GUI application, and as 2s-complement hexadecimal values. These coefficients need to be loaded into one of the four programmable coefficient banks in the A and B channel filters. The pass-band ripple of the channel filter is less than 0.15 dB and the stop-band attenuation is greater than 75 dB.

4.2 Test configuration and method

The following test set-up was used to assess the suitability of the suggested channel filter for DMR applications.

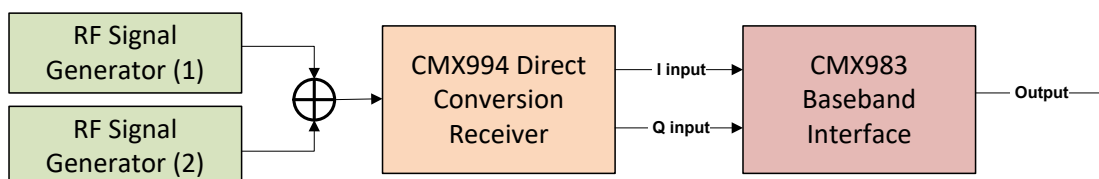


Figure 2 – Test set-up

A DMR 4-FSK signal was generated using an RF vector signal generator. This signal was then down converted to baseband I and Q signals using a CMX994 Direct Conversion Receiver. In these tests the CMX994 was used without any filtering of the RF test signals¹ - it was used purely to down-convert RF signals to baseband at suitable levels for the CMX983.

The baseband I/Q analogue signals were converted to 16-bit samples and filtered by the CMX983 channel filters. The resulting samples were then captured using the RX serial port and then demodulated in accordance with the DMR standard.

4.3 Test results

The following figures show the spectrum and eye-diagram of the received 4-FSK symbols captured at the output of the CMX983 after demodulation.

The received signal RF signal power for Figure 3 and Figure 4 was -64 dBm and -107 dBm respectively. Only the channel of interest was present at the RF input to the CMX994 receiver.

For reference Figure 5 shows the spectrum and eye-diagram at the DMR sensitivity limit i.e. when the SNR is 10dB. The SNR is set by a co-channel interferer: wanted = -107 dBm, interferer = -117 dBm.

To test the adjacent channel rejection capabilities of the filter an interfering channel with an average signal power 50 dB greater than the channel of interest and separated by 12.5 kHz was introduced to the test set-up. The spectrum and eye-diagram of Figure 6 clearly demonstrates the capability of the channel filter to successfully reject high power interfering adjacent channels. The interferer was used at +50 dB to keep the interfering signal within the CMX983 ADC dynamic range. ETSI EN 300 113 requires interferer rejection of at least +60 dB. This is demonstrated in the spectrum plot of Figure 6 where the interferer is attenuated by >20 dB relative to the wanted signal.

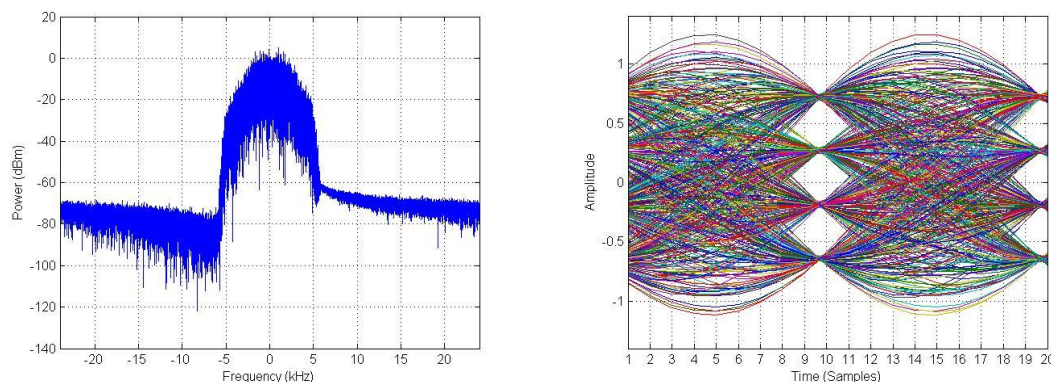


Figure 3 - Average received RF signal power -64 dBm

¹ With reference to the CMX994 Data Sheet, C3 and C4 are not fitted.

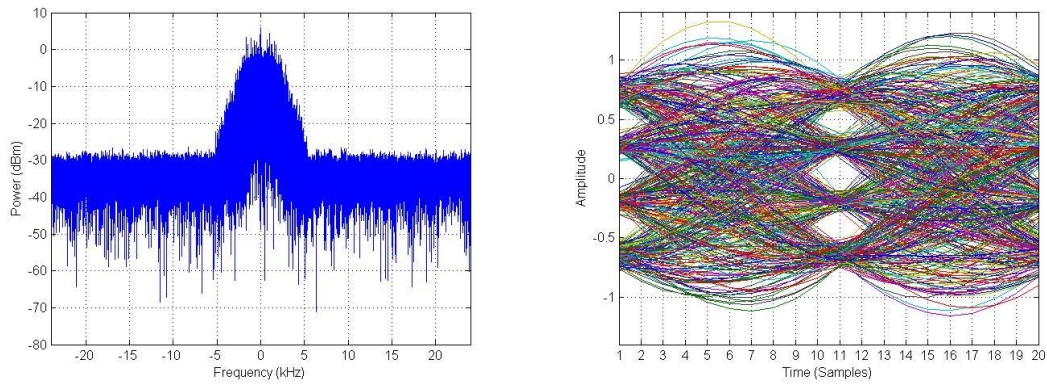


Figure 4 - Average received RF signal power -107 dBm

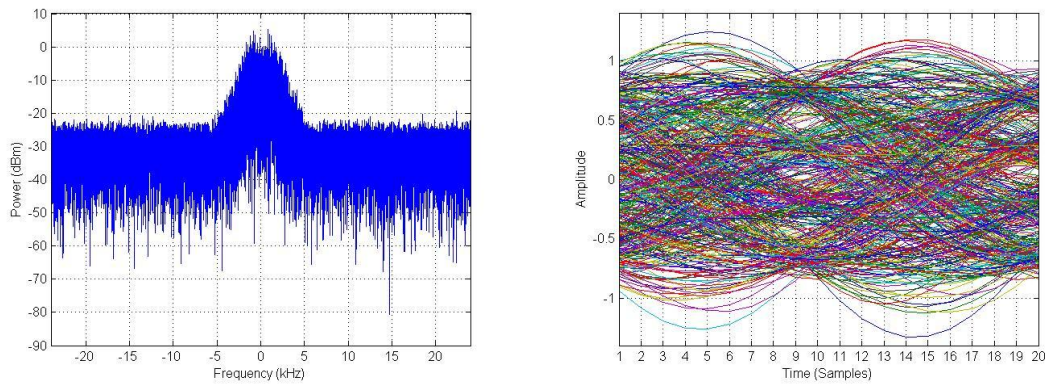


Figure 5 - DMR sensitivity limit when received SNR is 10 dB

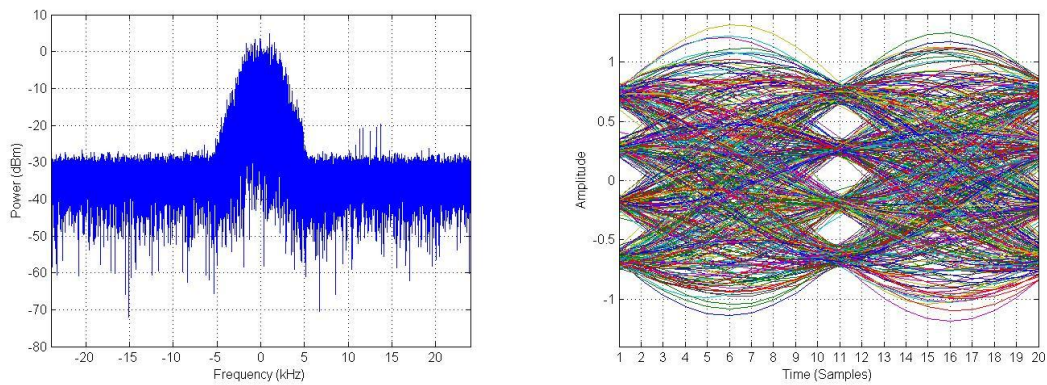


Figure 6 - Received signal with an adjacent interfering channel with signal power +50 dB separated by 12.5 kHz

5 Using the CMX983 with typical RF receivers

The DMR filter presented herein assumes the RF receiver provides no adjacent channel selectivity and has a flat frequency response across the signal bandwidth. In practical receivers some adjacent channel rejection is normally present because it helps optimise system dynamic range and interference rejection. Adjacent channel filtering often means that the signal passband response will no longer be flat. Small amounts of passband ripple can be compensated for in the CMX983 filter design however this must be done on a case-by-case basis. An example is given in the following section.

5.1 CMX994 receiver with adjacent channel filtering

The CMX994 provides a simple baseband I/Q filter as a single pole roll-off that can be modelled as outlined in the CMX994 Data Sheet. A typical configuration for DMR would use the CMX994 Datasheet component values for C3 & C4 with the “intermediate” filter bandwidth selected (b4,b3 = ‘01’ in CMX994 Rx Control Register \$12).

In this configuration the CMX994 will provide circa 10 dB of adjacent channel rejection however the passband requires compensation to achieve a good eye diagram. Figure 7 shows the received spectrum and eye diagram when the receive channel filter is also compensating for the CMX994 baseband I/Q filter roll-off. The results in Figure 8 are taken with an interfering channel (+60 dB) present. The CMX983 GUI application settings used when the adjacent channel is present are given in Figure 9.

Suitable filter coefficients that include compensation for the baseband I/Q filter are given in section 6.2 of this document.

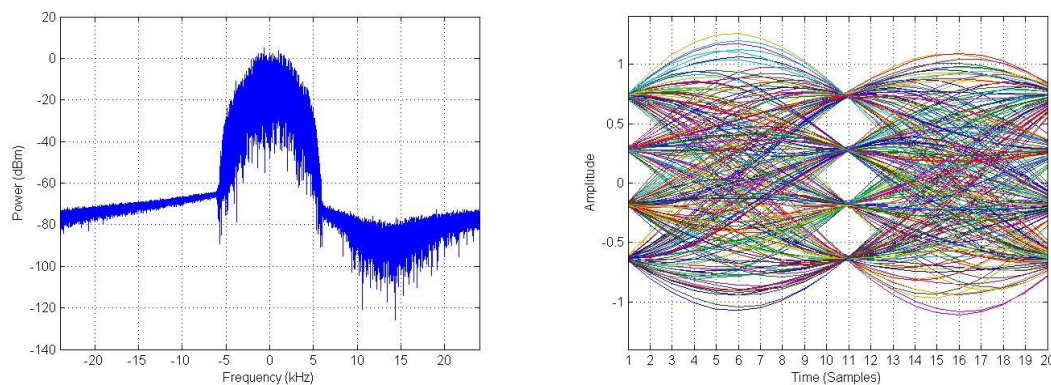


Figure 7 - Average received RF signal power -64 dBm

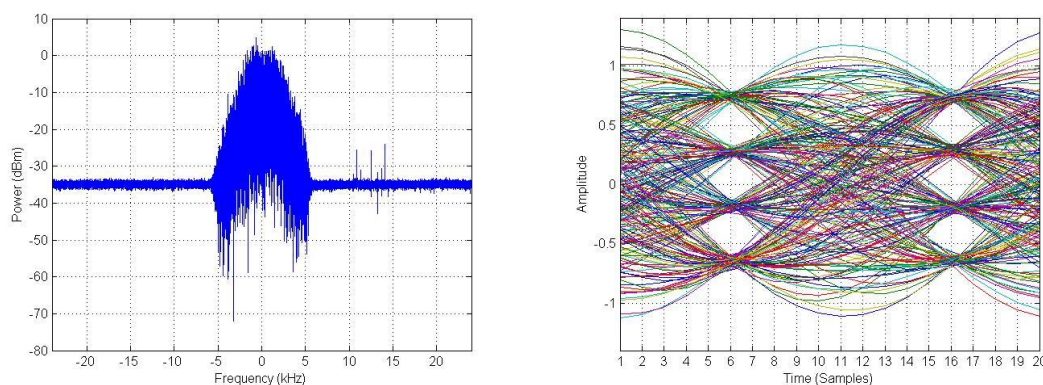


Figure 8 - Received signal (at -107 dBm) with an adjacent interfering channel with signal power +60 dB separated by 12.5 kHz

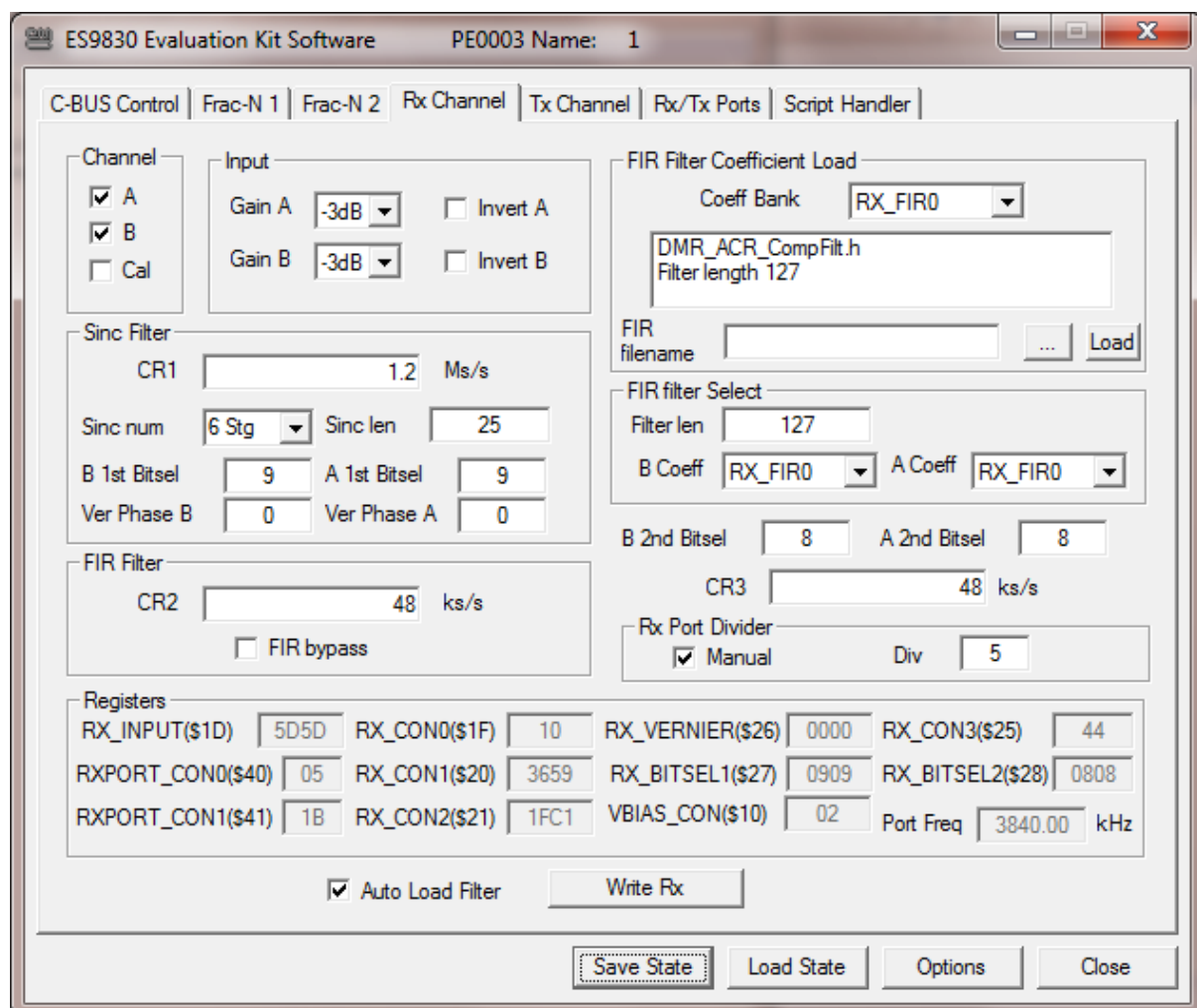


Figure 9 – GUI settings used in the presence of an interfering adjacent channel

6 Filter Coefficients

6.1 Standard Filter Coefficients

This section gives the filter coefficients that assume a flat frequency response across the signal bandwidth as used in Section 4.

6.1.1 Filter coefficient in ASCII format

The following coefficients are for use with the CMX983 GUI application. The coefficients must be re-formatted with a line break between each coefficient value. The file must be saved as an ASCII text file with a .h file extension. A suitable file is available to download from the CML website.

```
/*
DMR_ACR_UncompFilt10.h
FIR Filter
fixed point precision: 16 bits
*/
#define FILTER_TAP_NUM 127
static int filter_taps[FILTER_TAP_NUM] = {
4 31 58 92 117 119 88 26 -50 -113 -133 -95 -4 105 185 193 109 -41 -201 -292 -260 -97 139
350 427 313 29 -312 -559 -575 -318 131 585 825 705 228 -429 -977 -1136 -771 20 921 1514
1465 698 -531 -1704 -2243 -1778 -354 1515 3009 3322 2037 -601 -3658 -5755 -5538 -2209
4093 12215 20263 26167 28333 26167 20263 12215 4093 -2209 -5538 -5755 -3658 -601
2037 3322 3009 1515 -354 -1778 -2243 -1704 -531 698 1465 1514 921 20 -771 -1136 -977 -
429 228 705 825 585 131 -318 -575 -559 -312 29 313 427 350 139 -97 -260 -292 -201 -41
109 193 185 105 -4 -95 -133 -113 -50 26 88 119 117 92 58 31 4};
```

6.1.2 Filter coefficient as 2s-complement hexadecimal numbers

```
$0004, $001F, $003A, $005C, $0075, $0077, $0058, $001A, $FFCE, $FF8F, $FF7B, $FFA1,
$FFFC, $0069, $00B9, $00C1, $006D, $FFD7, $FF37, $FEDC, $FEFC, $FF9F, $008B,
$015E, $01AB, $0139, $001D, $FEC8, $FDD1, $FDC1, $FEC2, $0083, $0249, $0339,
$02C1, $00E4, $FE53, $FC2F, $FB90, $FCFD, $0014, $0399, $05EA, $05B9, $02BA,
$FDED, $F958, $F73D, $F90E, $FE9E, $05EB, $0BC1, $0CFA, $07F5, $FDA7, $F1B6,
$E985, $EA5E, $F75F, $0FFD, $2FB7, $4F27, $6637, $6EAD, $6637, $4F27, $2FB7,
$0FFD, $F75F, $EA5E, $E985, $F1B6, $FDA7, $07F5, $0CFA, $0BC1, $05EB, $FE9E,
$F90E, $F73D, $F958, $FDED, $02BA, $05B9, $05EA, $0399, $0014, $FCFD, $FB90,
$FC2F, $FE53, $00E4, $02C1, $0339, $0249, $0083, $FEC2, $FDC1, $FDD1, $FEC8,
$001D, $0139, $01AB, $015E, $008B, $FF9F, $FEFC, $FEDC, $FF37, $FFD7, $006D,
$00C1, $00B9, $0069, $FFFC, $FFA1, $FF7B, $FF8F, $FFCE, $001A, $0058, $0077, $0075,
$005C, $003A, $001F, $0004
```

6.2 Filter Coefficients when using CMX994

This section includes filter coefficients which assume the use of the CMX994 with adjacent channel filtering as detailed in section 5.1.

6.2.1 Filter coefficient in ASCII format

The following coefficients are for use with the CMX983 GUI application. The coefficients must be re-formatted with a line break between each coefficient value. The file must be saved as an ASCII text file with a .h file extension. A suitable file is available to download from the CML website.

```

/*
DMR_ACR_CompFilt10.h
FIR Filter
fixed point precision: 16 bits
*/
#define FILTER_TAP_NUM 127
static int filter_taps[FILTER_TAP_NUM] = {
1 1 0 1 3 5 5 3 0 -7 -12 -13 -5 7 22 30 23 0 -31 -58 -63 -34 23 87 124 106 25 -92 -197 -227 -
146 31 240 377 354 144 -190 -506 -638 -476 -39 514 929 966 525 -274 -1111 -1574 -1353 -
404 964 2173 2588 1805 -110 -2554 -4528 -4981 -3217 777 6238 11808 15957 17490 15957
11808 6238 777 -3217 -4981 -4528 -2554 -110 1805 2588 2173 964 -404 -1353 -1574 -1111
-274 525 966 929 514 -39 -476 -638 -506 -190 144 354 377 240 31 -146 -227 -197 -92 25
106 124 87 23 -34 -63 -58 -31 0 23 30 22 7 -5 -13 -12 -7 0 3 5 5 3 1 0 1 1};

```

6.2.2 Filter coefficient as 2s-complement hexadecimal numbers

```

$0001, $0001, $0000, $0001, $0003, $0005, $0005, $0003, $0000, $FFF9, $FFF4, $FFF3,
$FFFB, $0007, $0016, $001E, $0017, $0000, $FFE1, $FFC6, $FFC1, $FFDE, $0017, $0057,
$007C, $006A, $0019, $FFA4, $FF3B, $FF1D, $FF6E, $001F, $00F0, $0179, $0162, $0090,
$FF42, $FE06, $FD82, $FE24, $FFD9, $0202, $03A1, $03C6, $020D, $FEEF, $FBA9,
$F9DA, $FAB7, $FE6C, $03C4, $087D, $0A1C, $070D, $FF92, $F606, $EE50, $EC8B,
$F36F, $0309, $185E, $2E20, $3E55, $4452, $3E55, $2E20, $185E, $0309, $F36F, $EC8B,
$EE50, $F606, $FF92, $070D, $0A1C, $087D, $03C4, $FE6C, $FAB7, $F9DA, $FBA9,
$FEEF, $020D, $03C6, $03A1, $0202, $FFD9, $FE24, $FD82, $FE06, $FF42, $0090, $0162,
$0179, $00F0, $001F, $FF6E, $FF1D, $FF3B, $FFA4, $0019, $006A, $007C, $0057, $0017,
$FFDE, $FFC1, $FFC6, $FFE1, $0000, $0017, $001E, $0016, $0007, $FFFB, $FFF3,
$FFF4, $FFF9, $0000, $0003, $0005, $0005, $0003, $0001, $0000, $0001

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