AN14588

Connect USB camera and show picture on LCD panel using i.MX RT1170

Rev. 1.0 — 12 August 2025

Application note

Document information

Information	Content
Keywords	AN14588, USB camera, RT1170, LCD
Abstract	This document describes how to connect a USB camera to get the picture and show it on the LCD panel in real time using i.MX RT1170 EVK.

1 Introduction

This document provides information on how to connect a USB camera to get the picture and show it on the LCD panel in real time using i.MX RT1170 EVK as shown in Figure 1.

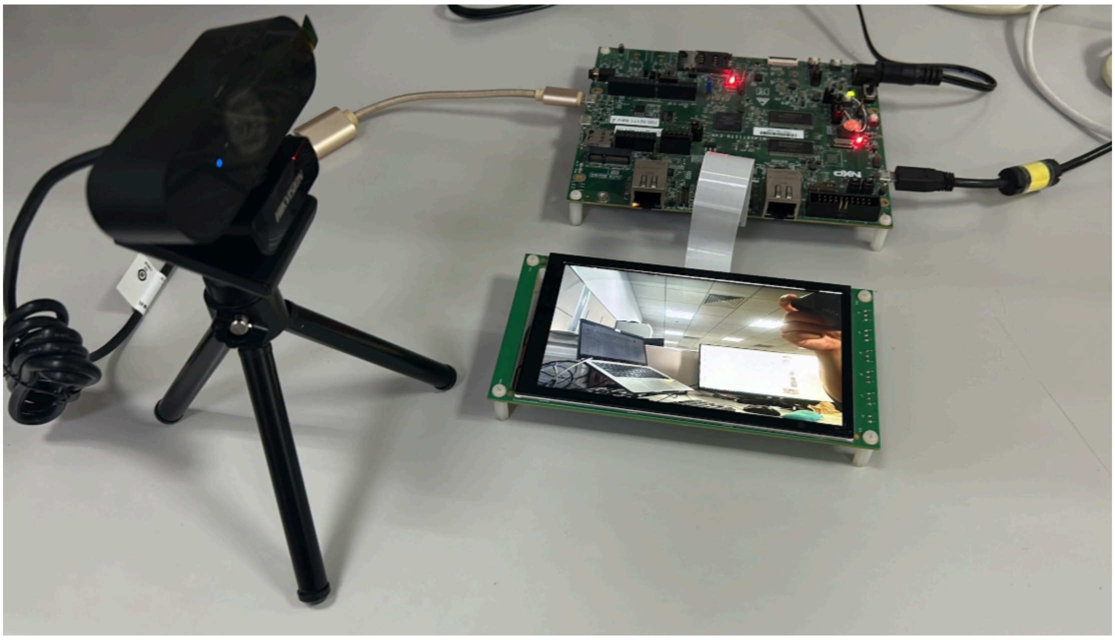


Figure 1. Connect USB camera and show picture on LCD panel using i.MX RT1170

2 How system runs

The way how the system runs is shown on Figure 2

At first, the 640*480 resolution picture in YUYV format is sent from the camera. Then it is scaled to be 1280*720 and rotated 270 degrees clockwise by PXP. The output picture size is 720*1280, which is displayed on an LCD panel.

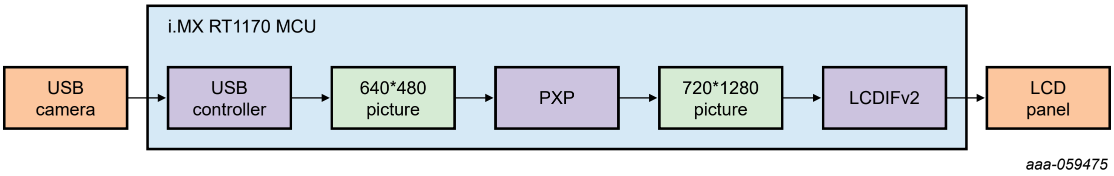


Figure 2. How system runs

3 Background knowledge

This section provides details on what background knowledge for USB Camera and PXP is required.

3.1 Background knowledge for USB camera

This chapter provides background information for the USB camera.

3.1.1 Basic parameters of a USB camera

Picture format

Typically, the picture format from a USB camera supports YUV and MJPEG. For real time application, use the YUV format to avoid decoding by CPU, which would cause delay and increase the CPU loading.

Resolution

The USB camera typically supports numerous resolutions, there are several examples below:

- w = 1920, h = 1080,
- w = 640, h = 480,
- w = 640, h = 360,
- w = 1280, h = 720,
- w = 1280, h = 960,
- w = 352, h = 288,
- w = 320, h = 240,
- w = 160, h = 120,

Frame rate

A USB camera reports the frame rate that it supports, there are several examples below:

- 30 fps
- 25 fps

3.1.2 Get information from class specific (CS) interface descriptor

The USB camera descriptor is organized as shown in Figure 3. There are format descriptors and frame descriptors. A USB camera has one or multi format descriptors, and one format descriptor includes one or multi frame descriptors.

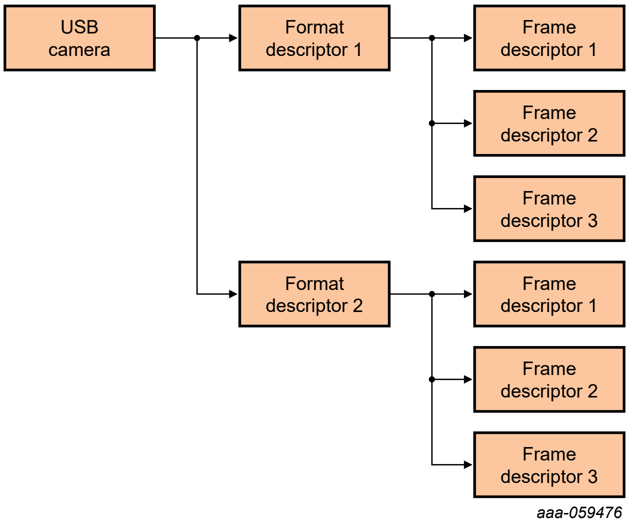


Figure 3. Descriptor structure

An example for a format descriptor is shown below.

Table 1. CS_INTERFACE Descriptor (27 bytes)

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bLength	8	1120	0x1B	0x1B	The descriptor size is 27 bytes.
bDescriptorType	8	1128	0x24	0x24	`CS_INTERFACE` descriptor type
bDescriptorSub Type1	8	1136	0x04	0x04	`VS_FORMAT_UNCOMPRESSED` descriptor subtype
bFormatIndex	8	1144	0x01	0x01	Index of this format descriptor
bNumFrame Descriptors	8	1152	0x03	0x03	Various frame descriptors following what corresponds to this format
guidFormat	32	1160	59555932-1000-800000AA389871	0x32595559	The globally unique identifier used to identify stream-encoding format 595559321000-800000AA-389B71
bBitsPerPixel	8	1288	0x10	0x10	Number of bits per pixel used to specify color in the decoded video frame
bDefaultFrame Index	8	1296	0x02	0x02	Optimum Index (used to select resolution) for this stream
bAspectRatioX	8	1304	0x00	0x00	The X dimension of the picture aspect ratio
bAspectRatioY	8	1312	0x00	0x00	The Y dimension of the picture aspect ratio
bmInterlaceFlags	8	1320	0x00	0x00	Specifies interlace information DO: Interlaced stream or variable 0 DI: Fields per frame 0 D2: Field 1 first O D3: Reserved O D5..4: Field pattern O

Table 1. CS_INTERFACE Descriptor (27 bytes)*...continued*

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
					D7..6: Display Mode O
bCopyProtect	8	1328	0x00	0x00	Specifies whether duplication of the video stream is restricted D0: video stream is restricted 0

An example for a frame descriptor is as below.

Table 2. CS_INTERFACE Descriptor (30 bytes)

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bLength	8	1576	0x1E	0x1E	The descriptor size is 30 bytes.
bDescriptorType	8	1584	0x24	0x24	`CS_INTERFACE` Descriptor Type
bDescriptorSub Type1	8	1592	0x05	0x05	`VS_FRAME_UNCOMPRESSED` descriptor subtype
bFrameIndex	8	1600	0x02	0x02	Index of this frame descriptor
bmCapabilities	8	1608	0x00	0x00	D0: Still image supported 0 D7..1: Reserved 0
wWidth	16	1616	0x0280	0x0280	Width of decoded bitmap frame in pixels
wHeight	16	1632	0x01E0	0x01E0	Height of decoded bitmap frame in pixels
dwMinBitRate	32	1648	01194000	0x01194000	Specifies the minimum bit rate at the longest frame interval in units of bit/s at which the data can be transmitted
dwMaxBitRate	32	1680	034BC000	0x034BC000	Specifies the maximum bit rate at the shortest frame interval in units of bit/s at which the data can be transmitted

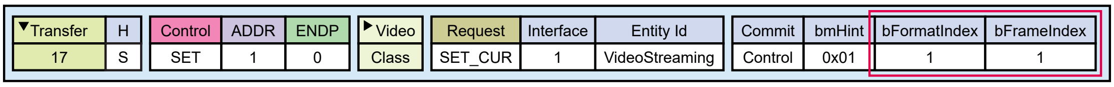
Table 2. CS_INTERFACE Descriptor (30 bytes)*...continued*

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
dwMaxVideo FrameBufferSize	32	1712	00096000	0x00096000	Specifies the maximum number of bytes that the compressor produces for a video frame or still image
dwDefaultFrame Interval	32	1744	00061A80	0x00061A80	Specifies the frame interval that the device would like to indicate for use by default
bFrameInterval Type	8	1776	0x01	0x01	Indicates how the frame interval can be programmed 0: Continuous frame interval 1..255: The number of discrete frames
dwFrame Interval(1)	32	1784	00061A80	0x00061A80	Longest frame interval supported (at lowest frame rate), in 100 ns units

From the CS interface descriptors, the important parameters are below:

- Bits per pixel: 16
- Frame format: `VS_FRAME_UNCOMPRESSED`
- Resolution: 640(0x280)*480(0x1E0)
- Interval: 40,000,000 (0x61A80) ns = 40 ms (Frame rate is 1000/40 = 25 fps)
- Buffer size: 614,400(0x96, 000) B = 640*480*2

The information would be decoded in the project code. Specify the working format CS descriptor and frame CS descriptor by the `SET_CUR` request according to the application requirement.



Transfer	H	Control	ADDR	ENDP	Video	Request	Interface	Entity Id	Commit	bmHint	bFormatIndex	bFrameIndex
17	S	SET	1	0	Class	SET_CUR	1	VideoStreaming	Control	0x01	1	1

Figure 4. SET_CUR request

3.1.3 Interface with multialternate setting

An interface has one or multiple alternate settings. Each alternate setting operates at a different bandwidth.

An example for an interface with an alternate setting 1 to support 3 ISO transaction per frame is shown below:

Table 3. INTERFACE descriptor (9 bytes)

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bLength	8	6968	0x09	0x09	The descriptor size is 9 bytes.
bDescriptorType	8	6976	0x04	0x04	INTERFACE descriptor type
bInterfaceNumber	8	6984	0x01	0x01	The number of this interface is 1.
bAlternateSetting	**8**	**6992**	**0x01**	**0x01**	**The value used to select the alternate setting for this interface is 1.**
bNumEndpoints	8	7000	0x01	0x01	The number of endpoints used by this interface is 1 (excluding endpoint zero)
bInterfaceClass	8	7008	0x0E	0x0E	The interface implements the Video class
bInterfaceSub Class	8	7016	0x02	0x02	The interface implements the SC_ VIDEOSTREAMING Subclass
bInterfaceProtocol	8	7024	0x00	0x00	The interface uses the `PC PROTOCOL UNDEFINED` Protocol
iInterface	8	7032	0x04	0x04	The interface string descriptor index is 4.

Table 4. ENDPOINT descriptor (7 bytes)

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bLength	8	7040	0x07	0x07	The descriptor size is 7 bytes.
bDescriptorType	8	7048	0x05	0x05	ENDPOINT Descriptor Type
bEndpointAddress	8	7056	0x82	0x82	This is an IN endpoint with endpoint number 2
bmAtributes	8	7064	0x05	0x05	Types - Transfer: ISOCHRONOUS Sync: Async Usage: Data EP
wMaxPacketSize	**16**	**7072**	**0x1400**	**0x1400**	**The maximum packet size for**

Table 4. ENDPOINT descriptor (7 bytes)*...continued*

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
					this endpoint is 1024. If Hi-Speed, 2 additional transactions per frame.
bInterval	8	7088	0x01	0x01	The polling interval value is every 1 frame. If Hi-Speed, every 1 uFrames

An example for an interface with an alternate setting 2 to support 2 ISO transaction per frame is shown below:

Table 5. INTERFACE descriptor (9 bytes)

Field	Length (bits) 8	Offset (bits)	Decoded	Hex Value	Description
bLength	8	7096	0x09	0x09	The descriptor size is 9 bytes.
bDescriptorType	8	7104	0x04	0x04	INTERFACE descriptor type
bInterfaceNumber	8	7112	0x01	0x01	The number of this interface is 1.
bAlternateSetting	**8**	**7120**	**0x02**	**0x02**	**The value used to select the alternate setting for this interface is 2.**
bNumEndpoints	8	7128	0x01	0x01	The number of endpoints used by this interface is 1 (excluding endpoint zero)
bInterfaceClass	8	7136	0x0E	0x0E	The interface implements the Video class
bInterfaceSub Class	8	7144	0x02	0x02	The interface implements the SC VIDEOSTRE AMING Subclass
bInterfaceProtocol	8	7152	0x00	0x00	The interface uses the PC PRO TOCOL UND EFINED Protocol
iInterface	8	7160	0x04	0x04	The interface string descriptor index is 4

Table 6. ENDPOINT descriptor (7 bytes)

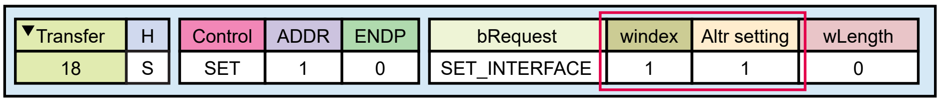
Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bLength	8	7168	0x07	0x07	The descriptor size is 7 bytes.

Table 6. ENDPOINT descriptor (7 bytes)*...continued*

Field	Length (bits)	Offset (bits)	Decoded	Hex Value	Description
bDescriptorType	8	7176	0x05	0x05	ENDPOINT Descriptor Type
bEndpointAddress	8	7184	0x82	0x82	This is an IN endpoint with endpoint number 2.
bmAttributes	8	7192	0x05	0x05	Types - Transfer ISOCHRONOUS Sync: Async Usage: Data EP
wMaxPacketSize	**16**	**7200**	**0x0C00**	**0x0C00**	**The maximum packet size for this endpoint is 1024 Bytes. If Hi-Speed, 1 additional transaction per frame.**
bInterval	8	7216	0x01	0x01	The polling interval value is every 1 Frame. If Hi-Speed, every 1 u Frames.

Note: *Verify that the bandwidth is sufficient to support the intended functionality. For some USB camera, multi-ISO in one micro frame is a must; otherwise, only part of the picture is transferred from the USB camera.*

To select a high-bandwidth alternate setting, use the `SET_INTERFACE` request as shown below.

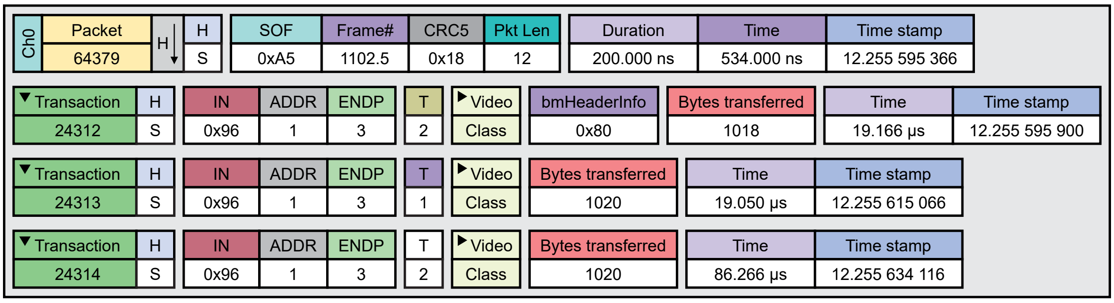


Transfer	H	Control	ADDR	ENDP	bRequest	windex	Altr setting	wLength
18	S	SET	1	0	SET_INTERFACE	1	1	0

aaa-059478

Figure 5. SET_INTERFACE request

Below is an example for image data transfer. There are 3 ISO transactions in 1 uFrame.



Ch0	Packet	H	H	SOF	Frame#	CRC5	Pkt Len	Duration	Time	Time stamp
	64379		S	0xA5	1102.5	0x18	12	200.000 ns	534.000 ns	12.255 595 366

Transaction	H	IN	ADDR	ENDP	T	Video	bmHeaderInfo	Bytes transferred	Time	Time stamp
24312	S	0x96	1	3	2	Class	0x80	1018	19.166 µs	12.255 595 900

Transaction	H	IN	ADDR	ENDP	T	Video	Bytes transferred	Time	Time stamp
24313	S	0x96	1	3	1	Class	1020	19.050 µs	12.255 615 066

Transaction	H	IN	ADDR	ENDP	T	Video	Bytes transferred	Time	Time stamp
24314	S	0x96	1	3	2	Class	1020	86.266 µs	12.255 634 116

aaa-059479

Figure 6. Example for image data transfer

3.2 Background knowledge for PXP

PXP is a 2-D image accelerator provided by NXP. It supports color space conversion, scaling, rotation, and blending.

The block diagram is shown in Figure 7.

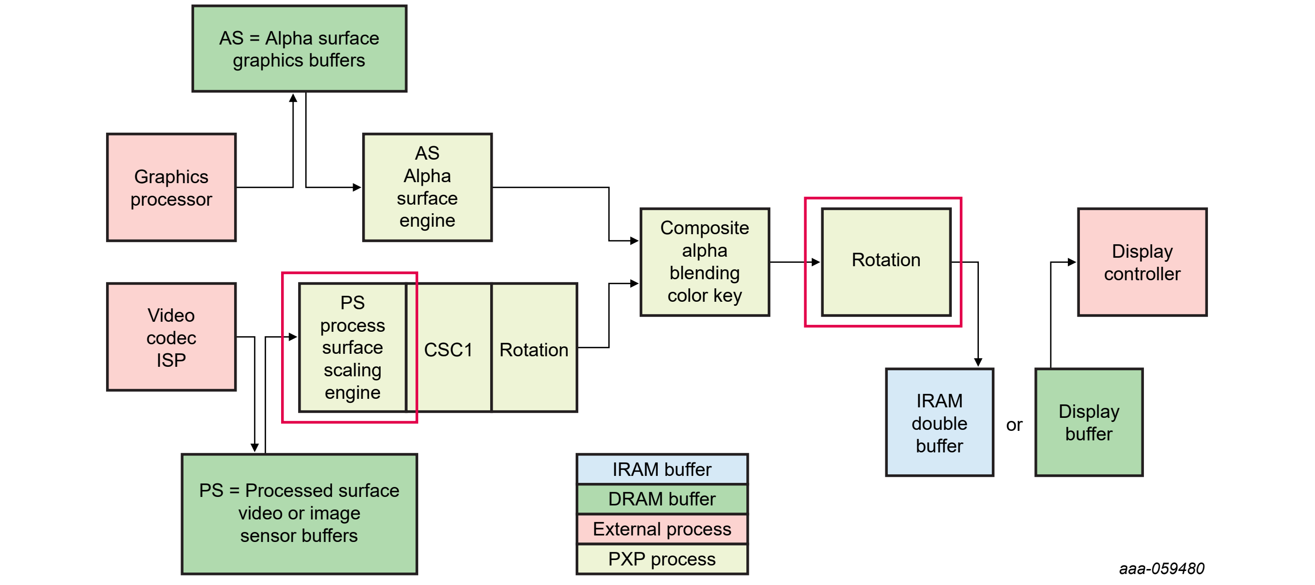


Figure 7. PXP block diagram

There are three domains in PXP: PS, AS, and OUTPUT.

If blending is not necessary, use the PS domain as input. From the PS domain input path, the image can be scaled and rotated.

In this document, the scaling engine and rotation unit marked in the red rectangle in the picture above are used.

The input image from the USB camera is 640 * 480. Then it is scaled to be 1280 * 720 and rotated to be 720*1280. Finally, the 720*1280 picture is sent to an LCD panel for display.

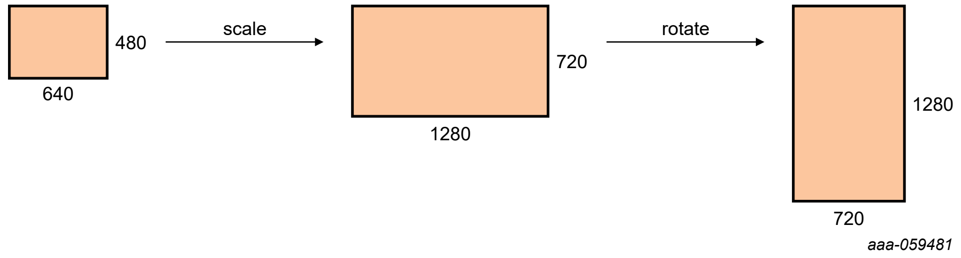


Figure 8. Scaling and rotation

To achieve this, configure the PS region correctly. For the case above, the PS region should be configured to be (0，0，1280-1，1280-1), which means, the upper left X, upper left Y, the lower right X, the lower right Y. After this configuration, the PS region should be as shown in Figure 9.

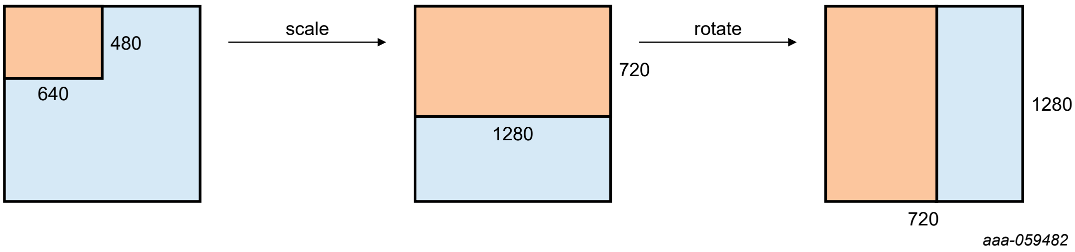


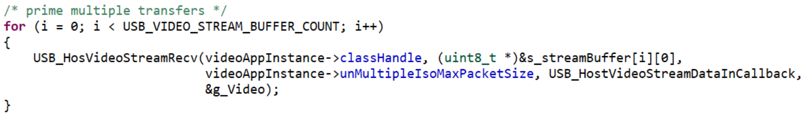
Figure 9. Configure the PS region

Here, since we configure the PS region to be a square of 1280*1280, then in the process of scaling and rotation, the whole picture is within the PS region range. For the range beyond PS region, PXP does not guarantee the data is correct. This is important in the PXP PS region configuration.

4 Keycode analysis

The process of getting picture data from the USB camera is as described below.

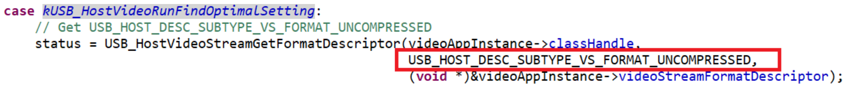
1. After enumeration, call `USB_HosVideoStreamRecv()` to prime USB RX transfers.



```
/* prime multiple transfers */
for (i = 0; i < USB_VIDEO_STREAM_BUFFER_COUNT; i++)
{
    USB_HosVideoStreamRecv(videoAppInstance->classHandle, (uint8_t *)&s_streamBuffer[i][0],
                           videoAppInstance->unMultipleIsoMaxPacketSize, USB_HostVideoStreamDataInCallback,
                           &g_Video);
}
```

Figure 10. Call USB_HosVideoStreamRecv() to prime USB RX transfers

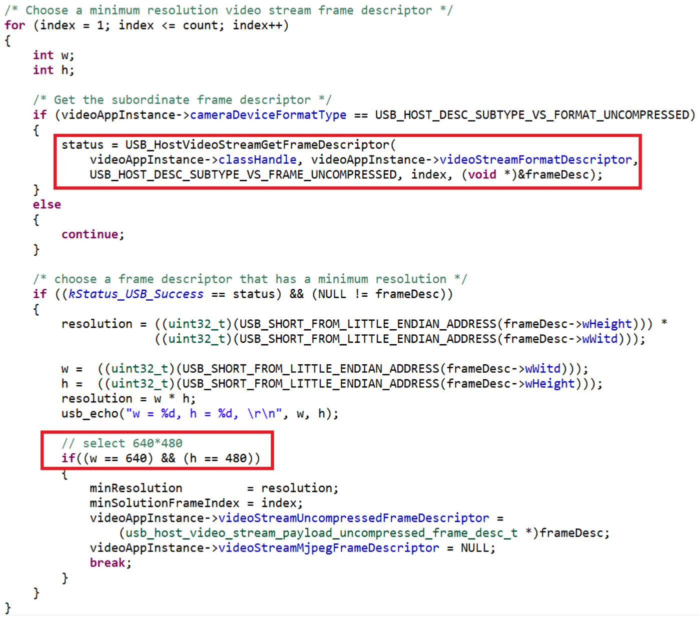
2. In the callback, call `USB_HosVideoStreamRecv()` again to start a new USB RX transfer as shown below.
3. Get an uncompressed format descriptor as shown in Figure 11



```
case kUSB_HostVideoRunFindOptimalSetting:
    // Get USB_HOST_DESC_SUBTYPE_VS_FORMAT_UNCOMPRESSED
    status = USB_HostVideoStreamGetFormatDescriptor(videoAppInstance->classHandle,
                                                    USB_HOST_DESC_SUBTYPE_VS_FORMAT_UNCOMPRESSED,
                                                    (void *)&videoAppInstance->videoStreamFormatDescriptor);
```

Figure 11. Get an uncompressed format descriptor

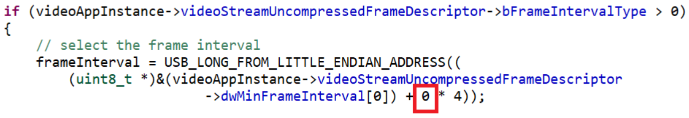
4. Get a frame descriptor and choose the one with the required resolution.



```
/* Choose a minimum resolution video stream frame descriptor */
for (index = 1; index <= count; index++)
{
    int w;
    int h;

    /* Get the subordinate frame descriptor */
    if (videoAppInstance->cameraDeviceFormatType == USB_HOST_DESC_SUBTYPE_VS_FORMAT_UNCOMPRESSED)
    {
        status = USB_HostVideoStreamGetFrameDescriptor(
            videoAppInstance->classHandle, videoAppInstance->videoStreamFormatDescriptor,
            USB_HOST_DESC_SUBTYPE_VS_FRAME_UNCOMPRESSED, index, (void *)&frameDesc);
    }
    else
    {
        continue;
    }

    /* choose a frame descriptor that has a minimum resolution */
    if ((kStatus_USB_Success == status) && (NULL != frameDesc))
    {
        resolution = ((uint32_t)(USB_SHORT_FROM_LITTLE_ENDIAN_ADDRESS(frameDesc->wHeight))) *
                     ((uint32_t)(USB_SHORT_FROM_LITTLE_ENDIAN_ADDRESS(frameDesc->wWitd)));

        w =  ((uint32_t)(USB_SHORT_FROM_LITTLE_ENDIAN_ADDRESS(frameDesc->wWitd)));
        h =  ((uint32_t)(USB_SHORT_FROM_LITTLE_ENDIAN_ADDRESS(frameDesc->wHeight)));
        resolution = w * h;
        usb_echo("w = %d, h = %d, \r\n", w, h);

        // select 640*480
        if((w == 640) && (h == 480))
        {
            minResolution         = resolution;
            minSolutionFrameIndex = index;
            videoAppInstance->videoStreamUncompressedFrameDescriptor =
                (usb_host_video_stream_payload_uncompressed_frame_desc_t *)frameDesc;
            videoAppInstance->videoStreamMjpegFrameDescriptor = NULL;
            break;
        }
    }
}
```

Figure 12. Get frame descriptor

5. Select a frame interval



```
if (videoAppInstance->videoStreamUncompressedFrameDescriptor->bFrameIntervalType > 0)
{
    // select the frame interval
    frameInterval = USB_LONG_FROM_LITTLE_ENDIAN_ADDRESS((
        (uint8_t *)&(videoAppInstance->videoStreamUncompressedFrameDescriptor
                     ->dwMinFrameInterval[0]) + 0 * 4));
```

Figure 13. Select a frame interval

6. Get a picture from a USB camera. When a picture from a USB camera is received, it is detected by the `USB_HostVideo_CheckOneFrameReady()` function, which processes the picture from the USB camera.
7. Process picture by the PXP. The function `APP_Scale_Rotate()` would be called to implement scaling and rotation by PXP.

5 Skills for optimization in MCUXpresso

In this case, the code must be optimized for performance; otherwise, visual artifacts (such as intermittent strips) may appear, as shown in Figure 14.

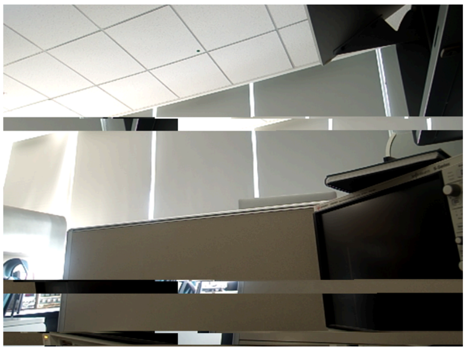


Figure 14. Strips

To avoid it, place some key code into TCM instead of running it in flash.

This is done by linkscripts in MCUXpresso.

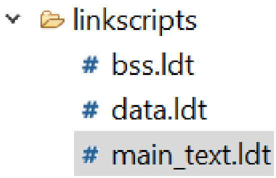


Figure 15. linkscripts in MCUXpresso

In `data.ldt`.

```
<#if memory.name=="SRAM_ITC_cm7">
*app.o(.text*)
*host_video.o(.text*)
*usb_host_hub_app.o(.text*)
*usb_host_hub.o(.text*)
*usb_host_video.o(.text*)
*usb_host_devices.o(.text*)
*usb_host_ehci.o(.text*)
*usb_host_framework.o(.text*)
*usb_host_hci.o(.text*)
*port.o(.text*)
```

```
*heap_4.o(.text*)
*croutine.o(.text*)
*event_groups.o(.text*)
*list.o(.text*)
*queue.o(.text*)
*stream_buffer.o(.text*)
*tasks.o(.text*)
*timers.o(.text*)
</#if>
```

In `main_text.ldt:`

```
*(EXCLUDE_FILE(
*app.o
*host_video.o
*usb_host_hub_app.o
*usb_host_hub.o
*usb_host_video.o
*usb_host_devices.o
*usb_host_ehci.o
*usb_host_framework.o
*usb_host_hci.o
*port.o
*heap_4.o
*croutine.o
*event_groups.o
*list.o
*queue.o
*stream_buffer.o
*tasks.o
*timers.o
) .text*)
```

In `bss.ldt:`

```
<#if memory.name=="SRAM_OC1">
*(.bss*)
</#if>
```

6 HW setup

For HW setup, refer to Figure 1.

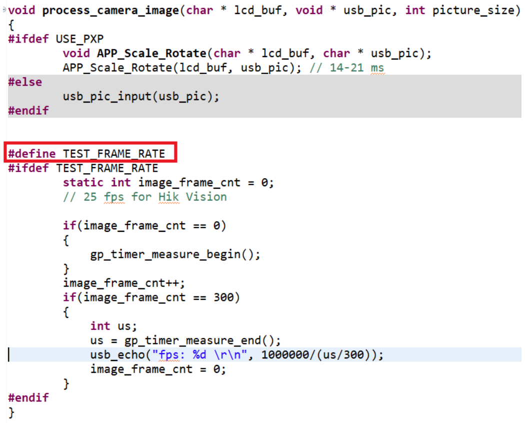
Power the board by a power adapter instead of a USB cable.

The below camera is tested in this AN:

1. HIK VISION E14
2. Logi C270
3. Newman NM-13-2K.

7 Performance test

To test the performance (frame rate), enable the `TEST_FRAME_RATE` in function `process_camera_image()` as shown below:



```
void process_camera_image(char * lcd_buf, void * usb_pic, int picture_size)
{
#ifdef USE_PXP
        void APP_Scale_Rotate(char * lcd_buf, char * usb_pic);
        APP_Scale_Rotate(lcd_buf, usb_pic); // 14-21 ms
#else
        usb_pic_input(usb_pic);
#endif


#define TEST_FRAME_RATE
#ifdef TEST_FRAME_RATE
        static int image_frame_cnt = 0;
        // 25 fps for Hik Vision

        if(image_frame_cnt == 0)
        {
            gp_timer_measure_begin();
        }
        image_frame_cnt++;
        if(image_frame_cnt == 300)
        {
            int us;
            us = gp_timer_measure_end();
            usb_echo("fps: %d \r\n", 1000000/(us/300));
            image_frame_cnt = 0;
        }
#endif
}
```

Figure 16. Performance test

From the console, the frame rate is 25 fps, it matches the 25 fps declared in the frame descriptor from the USB camera, see Section 3.1.1.

8 Revision history

Table 7. Revision history

Document ID	Release date	Description
AN14588 v.1.0	12 August 2025	Initial version

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