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| **MS-003** | | | | | | | | |
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| **嵌入式软件详细设计说明书** | | | | | | | | |
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文档更改履历

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**保密条款**

文档仅限产品（项目）组内流转，违者负相应法律责任。

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# 引言

## 编写目的

为了规范及保证MS-003项目工作合理有序地开展，经概要设计评审后进一步细化，本文对MS-003 台车控制板嵌入式软件、升降控制板嵌入式软件的总体架构设计进行详细描述，明确软件框架和系统运行流程、模块之间的关联，包括系统优先级，以及其他各种主要问题的解决方案，为项目的嵌入式软件编程[设计](https://baike.baidu.com/item/%E8%AF%A6%E7%BB%86%E8%AE%BE%E8%AE%A1/4136810" \t "_blank)提供基础。

本项目嵌入式软件概要设计说明书用于MS-003，并面向项目组全体成员。

## 项目背景

MS-003导航台车包含显示器、双目相机、按钮以及电源。

MS-003执行台车包含机械臂控制箱、工作站、按钮、台车控制板、升降控制板以及电源。

MS-003操作台车包含显示器、鼠标键盘、按钮以及电源。

三坛初期的台车升降是通过中间一个独立的升降立柱实现的，它体积大需要占用台车中间一个较大的空间，限制了其他部件的布局，升降过程中需要对抗较大的弯矩，手术中不允许有晃动，对其自身的刚性和可靠性提了较高的要求。

升降脚撑，分成4个单独的电动推杆，安装在台车底部四周，每个推杆不需要承受过多的弯矩即可以让台车保持比较稳定的状态，由于每个推杆可以单独运动，当遇到地面不平的情况，也可以自动调平。

## 术语及缩写词

台车控制板：实现机械臂开关机脚踏信号扩展输出、状态指示灯光控制、UPS通讯关机等功能的线路板。

升降控制板：实现升降立柱控制、运动互锁、刷新加速度计对台车进行调平触地的控制电路板。

几种灯板：实现灯光指示功能的电路板。

UPS：不间断电源(Uninterruptible Power Supply)，是一种含有储能装置的不间断电源。主要用于给部分对电源稳定性要求较高的设备，提供不间断的电源。

GPIO：（英语：General-ppose input/output），通用型之输入输出的简称，功能类似8051的P0—P3，其接脚可以供使用者由程控自由使用，PIN脚依现实考量可作为通用输入（GPI）或通用输出（GPO）或通用输入与输出（GPIO），如当clk generator, chip select等。

UART：通用异步收发传输器（Universal Asynchronous Receiver/Transmitter)，它将要传输的资料在串行通信与并行通信之间加以转换。

PWM：脉冲宽度调制（Pulse Width Modulation，PWM）简称脉宽调制。

USB：英文Universal Serial Bus（通用串行总线）的缩写，是一个外部总线标准，用于规范电脑与外部设备的连接和通讯，是应用在PC领域的接口技术。

## 参考资料

《技术需求规格书》

《STM32F1开发指南-库函数版本\_V3.1 》

《STM32F103xC数据手册》

《TPS54202数据表》

《RZ7899数据手册》

## 系统设计原则

软件系统设计要遵循安全性、合理性、经济性、实用性和规范性等原则。

## 编程环境

表1.6－1 编程环境

|  |  |
| --- | --- |
| 操作系统 | Windows 64位 |
| 数据库 | STM32库函数 |
| 串口调试工具 | sscom5.13.1 |
| 编程工具 | STM32CubeIDE V1.4.0 |
| 其他 | Visual Studio Code |

# 任务概述

## 目标

开发本软件系统的预期目标：旨在规范及保证MS-003项目工作合理有序地开展，作一个任务目标的阐述和总体系统框架结构的设计，明确系统处理流程、各个模块及模块之间的关联、以及其他各种主要问题的解决方案。

## 需求概述

根据《MS-003产品技术需求规格书V1.0》需要台车控制板实现机械臂开关机自由拖动定位、状态指示灯光控制和UPS通讯关机等功能。

根据《MS-003产品技术需求规格书V1.0》需要升降控制板实现多个立柱电源控制，以实现台车在升降时保持水平状态。

表2.3－1 功能说明

|  |  |  |  |
| --- | --- | --- | --- |
| **执行台车功能需求** | | | |
| **输入需**  **求序号** | **功能需求** | **硬件实现方式** | **功能说明** |
| TR150202 | 开关按钮：台车升、降按钮各1个（包含指示灯） | 设计控制板，实现台车升降和调平功能 | 见3.2升降控制板详细说明 |
| TR150204 | 开关按钮：系统开机按钮1个（包含指示灯） | 设计台车控制板外接一个带灯按钮实现机械臂开关机 | 见3.1台车控制板详细说明 |
| TR150302 | 灯光：UPS充电状态指示灯1个 | 设计台车控制板进行UPS充电状态查询并进行灯光指示 | 见3.1台车控制板详细说明 |
| TR150303 | 灯光：系统供电状态指示灯1个，未上电灯灭，电源供电蓝色，UPS供电黄色 | 设计台车控制板进行UPS状态查询并进行灯光指示 | 见3.1台车控制板详细说明 |
| TR150304 | 灯光：UPS充电状态指示灯1个。充电时显示蓝色。不充电时熄灭。 | 设计台车控制板进行UPS充电状态灯光指示 | 见3.1台车控制板详细说明 |
| TR150305 | 灯光：系统供电状态指示灯1个，未上电灯灭。电源供电时显示蓝色，UPS供电时显示黄色。 | 设计台车控制板进行系统供电状态灯光指示 | 见3.1台车控制板详细说明 |
| TR150601 | 台车组成：机械臂及控制箱 | 设计控制板，与机械臂和机械臂控制箱协同工作 | 见3.1台车控制板详细说明与3.2升降控制板详细说明 |
| TR150602 | 台车组成：UPS（UPS供电时，需要提示声音） | 系统包含UPS系统，同时设计控制板，与UPS协同工作 | 见3.1台车控制板详细说明 |
| TR150603 | 台车组成：UPS（UPS供电时，需要提示声音） | 系统包含UPS系统，同时设计UPS控制板，与UPS协同工作 | 见3.1台车控制板详细说明 |
| TR150606 | 台车组成：升降脚撑 | 系统包含升降脚撑，同时设计控制板，控制升降脚撑工作 | 见3.2升降控制板详细说明 |
| TR150801 | 台车升降：台车的升降由“台车升”和“台车降”按钮控制，行程不少于6cm。  升降按钮的信号接升降控制板和机械臂控制箱，台车升降时，机械臂不可运动或拖动。机械臂运动过程中，控制箱有信号发送给升降控制板，台车不可升降。 | 设计升降控制器，实现此功能 | 见3.2升降控制板详细说明 |
| **其他功能需求** | | | |
| **输入需**  **求序号** | **功能需求** | **硬件实现方式** | **功能说明** |
| TR180105 | 供电状态指示灯 | 按供电状态指示灯功能定义设计台车控制板程序 | 见3.1台车控制板详细说明 |

# 总体设计及各模块功能和框图

MS-003系统在形态上可划分为导航台车01、执行台车02、操作台车03和工具包04。

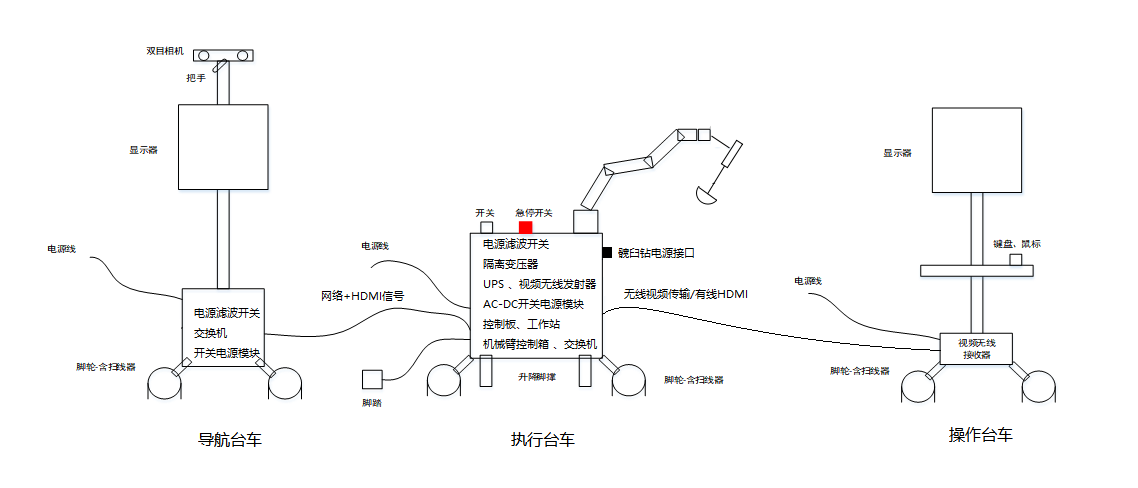


图3-1 MS-003总体框图



图3-2 导航台车信号连接图



图3-3 导航台车供电连接图



图3-4 执行台车信号连接图



图3-5 执行台车供电连接图



图3-6 操作台车原理框图

## 台车控制板详细说明

MS-003台车控制板集成了按键、脚踏和机械臂以及工作站工作状态信号输入、各状态灯的指示、与UPS的USB通讯及控制机械臂开关机等功能，对台车控制板编程实现上述功能，并结合产品应用场景，完善控制，提高产品应用便捷性，辅助手术导航设备进行精确操作。

### 软件结构

#### 总体框架



图3.1.1.1-1 台车控制板总体框图

#### 代码目录结构

工程文件目录结构

1. FWLIB - 硬件相关的底层驱动文件,官方提供的外设固件库

文件前缀为stm32f10x\_，硬件驱动的接口函数从这些文件中调用，一般不作修改。

1. CMSIS-core,CMSIS-startup - 官方提供的内核文件，启动文件

一般不作修改。

1. BSP - 用户编写的驱动文件，直接调用FWLIB与CMSIS中的底层文件

表3.1.1.2-1 相关配置的文件

|  |  |  |
| --- | --- | --- |
| 序号 | 文件名 | 功能描述 |
| 1 | bsp\_sys.c | 配置系统时钟，调试接口。 |
| 2 | bsp\_adc.c | 定义ADC相关变量及实现ADC初始化函数。 |
| 3 | bsp\_dma.c | DMA通道，模式配置。 |
| 4 | bsp\_usart.c | 串口的硬件参数配置。 |
| 6 | bsp\_timers.c | 定时器中断配置。 |
| 7 | bsp\_flash.c | MCU内部读写配置。 |
| ... |  |  |

1. FreeRTOSv2022 - 实时操作系统驱动

包含FreeRTOS官方提供的源码文件和头文件，除FreeRTOSConfig.h外其余文件一般不作修改。FreeRTOSConfig.h主要是对FreeRTOS内核参数进行配置，包括系统节拍设置、任务栈大小设置、相关API的启用/停用宏开关等。

1. Module-任务模块文件

表3.1.1.2-2 相关模块的文件

|  |  |  |
| --- | --- | --- |
| 序号 | 文件名 | 功能描述 |
| 1 | system\_cfg.c | MCU的一些初始化配置。 |
| 2 | pvprintf.c | 配置Printf函数的复用函数。 |
| 3 | vtask\_usart.c | 串口中断，接收数据处理的任务。 |
| 4 | vtask\_usb.c | 与UPS通信，发送控制指令接收数据处理的任务。 |
| 5 | vtask\_onoff.c | 控制机械臂与工作站开关机的任务。 |
| 6 | vtask\_led.c | 控制系统运行指示灯和其他状态指示灯的任务。 |
| 7 | vtask\_cpu.c | 统计各任务CPU和运存使用率的任务。 |

1. APP - 用户文件

本层只调用Module与FreeRTOSv2022的.h文件，实现了与底层的隔离。

表3.1.1.2-3 用户文件

|  |  |  |
| --- | --- | --- |
| 序号 | 文件名 | 功能描述 |
| 1 | maic.c | 主函数运行，调用系统配置函数与任务创建函数。 |
| 2 | app.c | 创建各任务和相关任务变量，开启任务调度。 |

#### 缩写定义

标准外设库中的主要外设均采用了缩写的形式，通过这些缩写可以很容易的辨认对应的外设。

表3.1.1.4-1 外设缩写定义

|  |  |
| --- | --- |
| 缩写 | 外设/单元 |
| ADC | 模数转换器 |
| BKP | 备份寄存器 |
| CAN | 控制器局域网模块 |
| CRC | CRC计算单元 |
| DAC | 数模转换器 |
| DBGMCU | 调试支持 |
| DMA | 直接内存存取控制器 |
| EXTI | 外部中断事件控制器 |
| FLASH | 闪存存储器 |
| FSMC | 灵活的静态存储器控制器 |
| GPIO | 通用输入输出 |
| I2C | I2C接口 |
| IWDG | 独立看门狗 |
| PWR | 电源/功耗控制 |
| RCC | 复位与时钟控制器 |
| RTC | 实时时钟 |
| SDIO | SDIO接口 |
| SPI | 串行外设接口 |
| TIM | 定时器 |
| USART | 通用同步/异步收发器 |
| WWDG | 窗口看门狗 |

#### 变量类型定义

表3.1.1.5-1 变量类型定义

|  |  |  |
| --- | --- | --- |
| uint32\_t | unsigned int | 无符号32位数据 |
| uint16\_t | unsigned short int | 无符号16位数据 |
| uint8\_t | unsigned char | 无符号8位数据 |

stm32f10x.h文件中还包含了常用的布尔形变量定义，如：

typedef enum {RESET = 0, SET = !RESET} FlagStatus, ITStatus；

typedef enum {DISABLE = 0, ENABLE = !DISABLE} FunctionalState；

#define IS\_FUNCTIONAL\_STATE(STATE) (((STATE) == DISABLE) || ((STATE) == ENABLE))；

typedef enum {ERROR = 0, SUCCESS = !ERROR} ErrorStatus。

### 主程序设计说明

#### 程序描述

表3.1.2.1-1 台车控制板功能列表

|  |  |  |
| --- | --- | --- |
| 序号 | 软件功能名称 | 软件功能 |
| 1 | 按键 | 检测按键状态，执行工作站或机械臂开关机 |
| 2 | 与工作站通讯 | 获取控制指令 |
| 3 | 工作站与机械臂工作状态检测 | 检测工作状态，确定UPS关机模式 |
| 4 | 髋臼钻 | 控制髋臼钻电源通断 |
| 5 | USB通信 | 获取UPS状态，控制UPS关机 |
| 6 | 灯光 | 依据工况，控制灯光状态 |

按键：控制机械臂开关机。当机械臂处于关机状态时，按一下按键机械臂进入开机状态；当机械臂处于开机状态时，按一下按键机械臂进入关机状态。

机械臂反馈及上下电：机械臂关机状态下，机械臂开关机按钮按下后信号传输到单片机，单片机接收到按键信号后点亮对应按键灯再发出信号给控制箱，将控制箱上电，机械臂启动后输出一个高电平给台车控制板；机械臂开机状态下，机械臂开关机按钮按下后信号传输到单片机，单片机接收到按键信号后熄灭对应按键灯再发出给控制箱，将控制箱关机，机械臂关机后无高电平输出给台车控制板。台车控制板通过检测该电平，确定机械臂的工作状态。

工作站工作状态检测：台车控制板检测与工作站相连的USB接口，判断是否有5V供电，确定工作站的工作状态。

USB通信电路：获取当前UPS的状态，若市电供电则点亮蓝灯；若UPS供电则点亮黄灯；若UPS处于充电状态则点亮充电指示灯。检测负载情况，若当前工作站或者机械臂处于工作状态，关闭市电供电，台车控制板通过串口命令控制UPS延迟5min关闭；若当前工作站和机械臂均处于关机状态，关闭市电供电，台车控制板通过串口命令控制UPS立即关闭。

灯光：依据当前工作状态，点亮对应指示灯。

#### 程序逻辑

程序先执行各种初始化，创建任务，开启任务调度器，按键任务、UPS通讯任务、指示灯任务、等任务运行。对于不同的任务设置不同的任务阻塞时间，为确保其它任务占用资源的可靠性，每个任务设置的阻塞时间不小于5ms。每1s与UPS通讯获取UPS当前状态，判断供电模式标志位和UPS电池标志位，并点亮或熄灭对应指示灯。串口指令处理任务10ms检测一次，若串口空闲中断来临，即处理串口数据。



图3.1.2.2-1 台车控制板软件流程图

### 定时器模块设计说明

#### 程序描述

初始化定时器，并启用定时器中断，定时器模块要求每0.1ms产生一次中断用于计数。计数的目的是用来统计CPU资源的使用情况;FreeRTOS的系统时钟为1000Hz,用于统计任务运行的定时器中断频率应大于1000Hz。

#### 程序逻辑

定时器中断程序中每0.1ms产生1次定时器中断，cpu使用率计数从0开始每中断一次加1，计数频率为RTOS系统频率10倍。



图3.1.3.2-1 定时器模块程序流程图

### USB模块设计说明

#### 程序描述

USB模块用于台车控制板和UPS通讯，发送命令获取UPS各状态及对UPS进行关机或延时关机操作。

#### 性能

具有一定的传输稳定性，即含有通讯协议，有发送和接收相应信号。

#### 程序逻辑

通讯协议采用标准Modbus RTU协议，台车控制板先将要发送的一帧数据写入USB芯片发送缓存区，再发送数据发出命令，USB芯片会将发送缓存区的数据发送给UPS，UPS接收到数据后，若数据符合协议且正确，UPS会返回一帧数据给USB芯片，此时USB芯片会将数据存入接收缓存区并产生一个中断，台车控制板检测到USB芯片中断，会发出数据读取命令从USB芯片接收缓存区读取UPS返回的数据。此时会产生串口接收中断，当接收完一帧数据后，对数据进行分析，先判断地址若地址不正确则不做处理；若地址正确再进行CRC计算若不正确不做处理；若CRC计算也正确，再判断数据位，并置位相应标志位。



图3.1.4.3-1 串口模块程序流程图

### 输入模块设计说明

#### 程序描述

该模块是用于采集人机交互按键输入以及工作站和UPS工作状态信号输入，并将信息转化为相应的标志位，通过标志位表征相应信息。

#### 性能

程序具有软件消抖功能，每5ms采集一次输入信息。

#### 程序逻辑

任务中每5ms执行一次输入信息扫描函数，高电平为1，低电平为0，将每次采样到的结果按数组低位至高位分别存至16bit的数组变量。扫描4次完成后，对数组变量进行“与”操作，即可判断按键状态并消除抖动。



图3.1.5.3-1 输入模块程序流程图

### 机械臂开关机模块设计说明

#### 程序描述

该模块是用于控制机械臂开关机，5ms检测一次开关机标志位并执行对应操作。

#### 性能

每5ms扫描一次按键状态，扫描后判断按键状态，根据按键状态的变化控制机械臂开关机同步化。

#### 程序逻辑

在任务中每5ms扫描一次机械臂状态标志位，若机械臂处于开机中状态，此时机械臂开关机按键灯0.5s闪烁一次，因机械臂正常开机需要70s左右，所以设置超时时间为100s；若开机完成检测到上电反馈信号，按键灯常亮机械臂处于开机状态，若超时时间结束还未检测到上电反馈信号，按键灯熄灭机械臂处于关机状态；若机械臂处于关机中状态，此时机械臂开关机按键灯1s闪烁一次，因机械臂正常关机需要15s左右，所以设置30s延时，此过程中按开关机按键无效，直到延时结束，按键灯熄灭，机械臂处于关机状态。



图3.1.6.3-1 机械臂开关机模块程序流程图

### 状态指示灯模块设计说明

#### 程序描述

该模块是用于控制状态指示灯，根据各状态标志位点亮或熄灭指示灯。

#### 程序逻辑

任务中10ms循环检测各状态标志位，若UPS电池充电标志位被置1则点亮电池充电状态指示灯；否则熄灭电池充电状态指示灯。若市电供电标志位被置1则点亮市电供电状态指示灯；否则熄灭市电供电状态指示灯。若UPS供电标志位被置1则点亮UPS供电状态指示灯；否则熄灭UPS供电状态指示灯。



图3.1.7.2 状态指示灯模块程序流程图

## 升降控制板详细说明

### 软件结构

#### 总体框架



图3.2.1.1-1 系统框架

#### 代码目录结构

工程文件目录结构

1. Core,User外部硬件相关的驱动文件

由软件根据配置生成，详述如下表：

表3.2.1.2-1 用户外部硬件相关的驱动文件

|  |  |  |
| --- | --- | --- |
| 序号 | 文件名 | 功能描述 |
| 1 | gpio.c | 配置gpio。 |
| 2 | adc.c | 定义ADC相关变量及实现ADC初始化函数。 |
| 3 | dma.c | DMA通道，模式配置。 |
| 4 | usart.c | 串口的硬件参数配置。 |
| 6 | tim.c | 定时器中断配置。 |

1. Driver - ST官方提供的外设固件库

包含ST官方提供的外设固件库源码文件和头文件，一般不作修改。

1. FreeRTOSv202112.00 - 实时操作系统驱动

包含FreeRTOS官方提供的源码文件和头文件，除FreeRTOSConfig.h外其余文件一般不作修改。FreeRTOSConfig.h主要是对FreeRTOS内核参数进行配置，包括系统节拍设置、任务栈大小设置、相关API的启用/停用宏开关等。

1. User - 用户文件

应用和应用接口源码文件和头文件，详述如下表：

表3.2.1.2-2 用户文件

|  |  |  |
| --- | --- | --- |
| 序号 | 文件名 | 功能描述 |
| 1 | app.h | 声明供外部调用的函数。 |
| 2 | app.c | 实现整体功能的应用层代码。 |
| 3 | adx345.h | 定义ADXL345的I2C地址及指令表，声明供外部调用的函数。 |
| 4 | adx345.c | 实现ADXL345的初始化及X、Y、Z轴AD值的读取等函数。 |
| 5 | iic.h | 定义ADXL345的I2C硬件，声明供外部调用的函数。 |
| 6 | iic.c | 实现I2C的通讯协议功能。 |
| 7 | key.h | 定义变量读取按键状态、定义按键标志位，声明供外部调用的函数。 |
| 8 | key.c | 实现按键状态扫描及按键检测。 |
| 9 | tc.h | 声明供外部调用的函数。 |
| 10 | tc.c | 实现运行灯控制、按键灯控制及电机输出控制等函数。 |

#### 缩写定义

ST官方提供的外设固件库中的主要外设均采用了缩写的形式，通过这些缩写可以很容易地辨认对应的外设。

表3.2.1.3-1 外设缩写定义

|  |  |
| --- | --- |
| 缩写 | 外设/单元 |
| ADC | 模数转换器 |
| BKP | 备份寄存器 |
| CAN | 控制器局域网模块 |
| CRC | CRC计算单元 |
| DAC | 数模转换器 |
| DBGMCU | 调试支持 |
| DMA | 直接内存存取控制器 |
| EXTI | 外部中断事件控制器 |
| FLASH | 闪存存储器 |
| FSMC | 灵活的静态存储器控制器 |
| GPIO | 通用输入输出 |
| I2C | I2C接口 |
| IWDG | 独立看门狗 |
| PWR | 电源/功耗控制 |
| RCC | 复位与时钟控制器 |
| RTC | 实时时钟 |
| SDIO | SDIO接口 |
| SPI | 串行外设接口 |
| TIM | 定时器 |
| USART | 通用同步/异步收发器 |
| WWDG | 窗口看门狗 |
| MSP | 芯片级支持包 |
| BSP | 板级支持包 |
| HAL | 硬件抽象层 |

#### 变量类型定义

表3.2.1.4-1 变量类型定义

|  |  |  |
| --- | --- | --- |
| u32 | uint32\_t | 无符号32位数据 |
| u16 | uint16\_t | 无符号16位数据 |
| u8 | uint8\_t | 无符号8位数据 |

stm32f10x.h文件中还包含了常用的布尔形变量定义，如：

1 typedef enum {RESET = 0, SET = !RESET} FlagStatus, ITStatus;

2 typedef enum {DISABLE = 0, ENABLE = !DISABLE} FunctionalState;

3 #define IS\_FUNCTIONAL\_STATE(STATE) (((STATE) == DISABLE) || ((STATE) == ENABLE))

4 typedef enum {ERROR = 0, SUCCESS = !ERROR} ErrorStatus;

### 主程序设计说明

#### 程序描述

表3.2.2-1 升降控制板功能列表

|  |  |  |
| --- | --- | --- |
| 序号 | 软件功能名称 | 软件功能 |
| 1 | 按键 | 检测按键状态，根据按键控制台车升降。 |
| 2 | 电动立柱 | 控制立柱实现升降，调平，触地。 |
| 3 | 与机械臂相互状态检测 | 检测工作状态，进行运动互锁控制。 |
| 4 | 加速度传感器 | 检测台车倾斜角度。 |
| 5 | 电流传感器 | 检测电流值，立柱触地控制。 |
| 6 | 灯光 | 依据工况，控制灯光状态。 |

按键：按上升键台车升，按下降键台车降。台车处于升降状态时按上升键或下降键运动均会停止。

与机械臂相互状态检测：机械臂运动状态下，机械臂会反馈一个开关量信号传输到控制板，控制板接收到信号后挂起电动立柱的控制任务，禁止电机运动。机械臂不运动时控制板恢复被挂起的电动立柱控制任务，若电动立柱处于运动状态控制板反馈一个开关量信号给机械臂。

加速度传感器：根据水平面x轴与y轴的加速分量可以得知台车水平倾斜的情况，在对台车调平控制时周期性读取加速度数据。

电流传感器：该电流传感器输出为电压值，根据传感器的电流 电压关系式可计算出流过电机的电流。电机动作时检测电流值大小对电机的负载进行判断，从而实现电动立柱的触地控制。

灯光：依据当前工作状态，点亮对应指示灯。

#### 程序逻辑

主程序先对时钟进行配置，再进行外设初始化，然后分别创建运行灯、按键检测、串口指令处理、电机控制、电机电流监控和加速度计等任务，在任务创建成功后启动任务调度器进入内核任务调度模式。升降控制板以调节台车水平并稳定支撑为核心功能。



图3.2.2.2-1 主程序流程

### 运行灯任务设计说明

#### 程序描述

该任务控制运行灯定期亮灭，用于指示程序是否处于运行状态。

#### 功能

定时翻转运行灯控制管脚。

#### 性能

运行灯控制管脚每1秒翻转一次。

#### 程序逻辑

运行灯任务程序逻辑比较简单，只需调用内核延时函数后任务便处于阻塞态，待任务唤醒后对运行灯的控制管脚进行翻转即可。

### 按键检测任务设计说明

#### 程序描述

该任务采集按键信息，并将按键信息转化为相应的标志位，通过标志位表征按键状态。

#### 功能

采集按键信息，交按键信息转化为相应的标志位，通过标志位表征按键状态。

#### 性能

程序具有消抖功能，每5ms采集一次按键信息。

#### 程序逻辑

实现过程为：系统节拍为1000Hz，故任务的执行周期为5ms。任务每执行一次扫描一次按键的状态，高电平为1，低电平为0，将每次采样到的结果按数组低位至高位分别存至16bit的数组变量。扫描16次完成后，对数组变量进行“与”操作，即可判断按键状态并消除抖动。根据获得的键值决定是否需要恢复处于挂起态的电机控制任务。

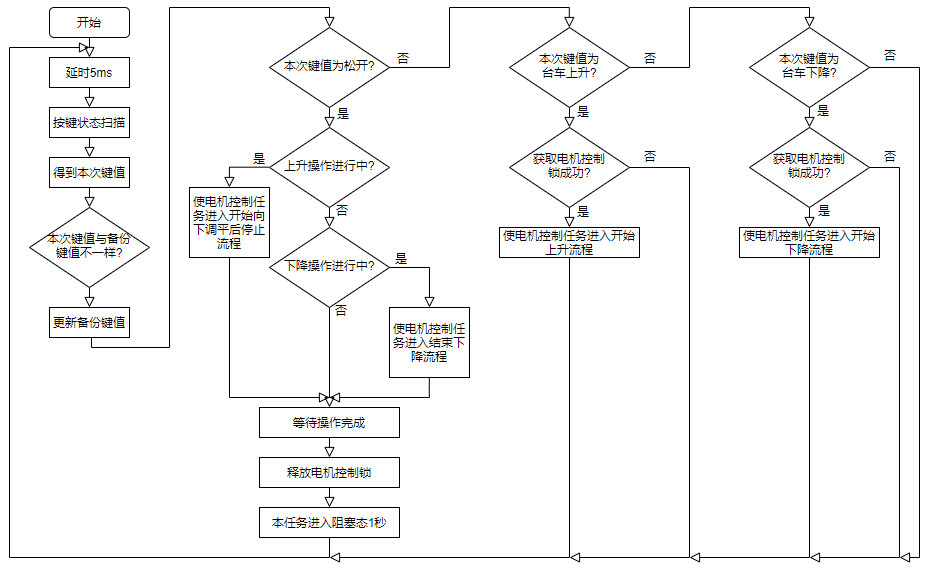


图3.2.4.4-1 按键检测任务工作流程

### 串口指令处理任务设计说明

#### 程序描述

该任务用于与上位机的通讯，可以接受上位机的串口指令并完成相应的操作。

#### 功能

接受上位机的串口指令并完成相应的操作。

#### 性能

具有一定的传输稳定性，即含有通讯协议，有发送和接收有响应信号。

#### 程序逻辑

实现过程为：当串口接收到上位机数据时，程序进入串口中断，接收上位机的数据并发送到串口接收数据消息队列；同时串口指令处理任务定时查询串口接收数据消息队列中可用数据的个数，如可用数据个数不为0且经过50ms后仍不增加判定一帧数据接收完成，此时便将串口接收数据消息队列中的数据全部读出至内存缓冲区并将其与预设协议进行比较，如一致则执行相应操作，如接收的数据出错，则向上位机反馈接收数据失败的指令。

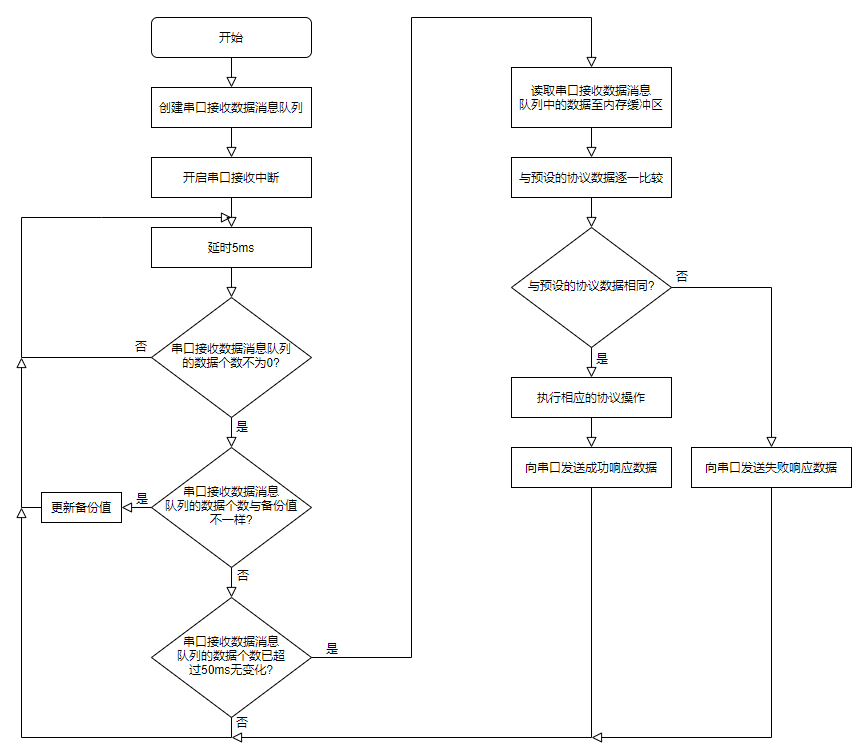


图3.2.5.4-1 串口指令处理任务工作流程

### 电机控制任务设计说明

#### 程序描述

该任务根据按键检测状态或串口指令对电机进行控制。

#### 功能

根据按键检测任务或串口指令处理任务发出的指示并配合加速度计和电机电流传感器控制台车在上升过程中尽量保持平衡。

#### 性能

在台车上升过程中具有自动调平衡的功能，自动根据加速度计返回的数据尽量使台车处于平衡状态，并能根据电机电流传感器返回的电流数据在任一立柱到达最高后自动停止。

#### 程序逻辑

电机控制任务创建成功后自动进入挂起态，等待按键检测任务或串口指令处理任务恢复才运行。在下降过程中不调节平衡，而在上升过程中则会根据加速度计返回的数据尽量使台车保持平衡，当电机电流传感器检测到任一立柱电流超过预设的阈值时自动停止上升操作。运动结束后会再次进入挂起态。

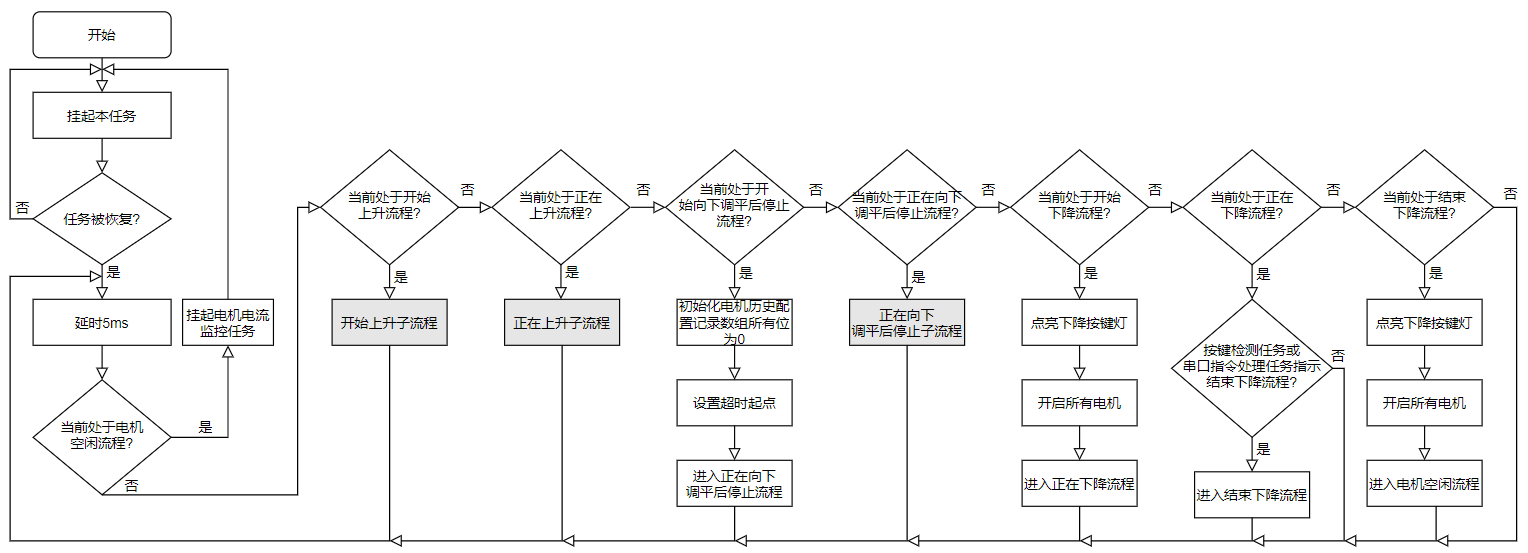
%3CmxGraphModel%3E%3Croot%3E%3CmxCell%20id%3D%220%22%2F%3E%3CmxCell%20id%3D%221%22%20parent%3D%220%22%2F%3E%3CmxCell%20id%3D%222%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20soce%3D%223%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22240%22%20y%3D%22110%22%20as%3D%22targetPoint%22%2F%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%223%22%20value%3D%22%E5%BC%80%E5%A7%8B%22%20style%3D%22rounded%3D1%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%2240%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%224%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BentryX%3D0.5%3BentryY%3D0%3BentryDx%3D0%3BentryDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20soce%3D%225%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22240%22%20y%3D%22179.99999999999977%22%20as%3D%22targetPoint%22%2F%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%225%22%20value%3D%22%E6%8C%82%E8%B5%B7%E6%9C%AC%E4%BB%BB%E5%8A%A1%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22110%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%226%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BentryX%3D0.5%3BentryY%3D0%3BentryDx%3D0%3BentryDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20target%3D%227%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22240%22%20y%3D%22259.9999999999998%22%20as%3D%22socePoint%22%2F%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%227%22%20value%3D%22%E5%BB%B6%E6%97%B65ms%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22290%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%228%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E7%94%B5%E6%9C%BA%E7%A9%BA%E9%97%B2%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22360%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%229%22%20value%3D%22%E4%BB%BB%E5%8A%A1%E8%A2%AB%E6%81%A2%E5%A4%8D%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22180%22%20width%3D%22160%22%20height%3D%2280%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2210%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0%3BexitY%3D0.5%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20soce%3D%229%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22130%22%20y%3D%22200%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%22240%22%20y%3D%2290%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%22140%22%20y%3D%22220%22%2F%3E%3CmxPoint%20x%3D%22140%22%20y%3D%2290%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2211%22%20value%3D%22%E5%90%A6%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22150%22%20y%3D%22205%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2212%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22250%22%20y%3D%22266%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2213%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E5%BC%80%E5%A7%8B%26lt%3Bbr%26gt%3B%E4%B8%8A%E5%8D%87%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2214%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E6%AD%A3%E5%9C%A8%E4%B8%8A%E5%8D%87%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22360%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2215%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E5%BC%80%E5%A7%8B%E5%90%91%26lt%3Bbr%26gt%3B%E4%B8%8B%E8%B0%83%E5%B9%B3%E5%90%8E%E5%81%9C%E6%AD%A2%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22560%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2216%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E6%AD%A3%E5%9C%A8%E5%90%91%E4%B8%8B%26lt%3Bbr%26gt%3B%E8%B0%83%E5%B9%B3%E5%90%8E%E5%81%9C%E6%AD%A2%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22760%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2217%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E5%BC%80%E5%A7%8B%26lt%3Bbr%26gt%3B%E4%B8%8B%E9%99%8D%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22960%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2218%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E6%AD%A3%E5%9C%A8%E4%B8%8B%E9%99%8D%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221160%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2219%22%20value%3D%22%E5%BD%93%E5%89%8D%E5%A4%84%E4%BA%8E%E7%BB%93%E6%9D%9F%E4%B8%8B%E9%99%8D%E6%B5%81%E7%A8%8B%3F%22%20style%3D%22rhombus%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3Bshadow%3D0%3BfontFamily%3DHelvetica%3BfontSize%3D12%3Balign%3Dcenter%3BstrokeWidth%3D1%3Bspacing%3D6%3BspacingTop%3D-4%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221360%22%20y%3D%22510%22%20width%3D%22160%22%20height%3D%22120%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2220%22%20value%3D%22%E6%81%A2%E5%A4%8D%E7%94%B5%E6%9C%BA%E7%94%B5%E6%B5%81%E7%9B%91%E6%8E%A7%E4%BB%BB%E5%8A%A1%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22660%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2221%22%20value%3D%22%E7%82%B9%E4%BA%AE%E4%B8%8A%E5%8D%87%E6%8C%89%E9%94%AE%E7%81%AF%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22730%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2222%22%20value%3D%22%E5%BC%80%E5%90%AF%E6%89%80%E6%9C%89%E7%94%B5%E6%9C%BA%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22800%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2223%22%20value%3D%22%E8%BF%9B%E5%85%A5%E6%AD%A3%E5%9C%A8%E4%B8%8A%E5%8D%87%E6%B5%81%E7%A8%8B%22%20style%3D%22rounded%3D0%3BwhiteSpace%3Dwrap%3Bhtml%3D1%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22160%22%20y%3D%22940%22%20width%3D%22160%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2224%22%20value%3D%22%E5%88%9D%E5%A7%8B%E5%8C%96%E7%94%B5%E6%9C%BA%E5%8E%86%E5%8F%B2%E9%85%8D%E7%BD%AE%E8%AE%B0%E5%BD%95%E6%95%B0%E7%BB%84%EF%BC%8C%E6%9C%80%E4%BD%8E%E4%BD%8D%E4%B8%BA1%E5%85%B6%E4%BD%99%E4%BD%8D%E4%B8%BA0%22%20style%3D%22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ddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221050%22%20y%3D%22637%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22113%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221250%22%20y%3D%22638%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22114%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221450%22%20y%3D%22637%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22115%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221250%22%20y%3D%22780%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22116%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22749%22%20y%3D%22809%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22117%22%20value%3D%22%E6%98%AF%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%22529%22%20y%3D%22978%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22118%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22440%22%20y%3D%221040%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%22240%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%22440%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22119%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22540%22%20y%3D%221110%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%22440%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%22540%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22120%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22740%22%20y%3D%221080%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%22640%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%22740%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22121%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%22860%22%20y%3D%221080%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%22740%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%22860%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22122%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%221240%22%20y%3D%22840.0000000000002%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%221040%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%221240%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22123%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D1%3BexitY%3D0.5%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20soce%3D%2268%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%221330%22%20y%3D%22720%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%221240%22%20y%3D%221140.5714285714284%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%221340%22%20y%3D%22715%22%2F%3E%3CmxPoint%20x%3D%221340%22%20y%3D%221141%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22124%22%20value%3D%22%E5%90%A6%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221330%22%20y%3D%22700%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22125%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20relative%3D%221%22%20as%3D%22geometry%22%3E%3CmxPoint%20x%3D%221520%22%20y%3D%22570.0000000000002%22%20as%3D%22socePoint%22%2F%3E%3CmxPoint%20x%3D%221440%22%20y%3D%221140%22%20as%3D%22targetPoint%22%2F%3E%3CArray%20as%3D%22points%22%3E%3CmxPoint%20x%3D%221550%22%20y%3D%22570%22%2F%3E%3CmxPoint%20x%3D%221550%22%20y%3D%221140%22%2F%3E%3C%2FArray%3E%3C%2FmxGeometry%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22126%22%20value%3D%22%E5%90%A6%22%20style%3D%22text%3Bhtml%3D1%3BstrokeColor%3Dnone%3BfillColor%3Dnone%3Balign%3Dcenter%3BverticalAlign%3Dmiddle%3BwhiteSpace%3Dwrap%3Brounded%3D0%3B%22%20vertex%3D%221%22%20parent%3D%221%22%3E%3CmxGeometry%20x%3D%221530%22%20y%3D%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3C%2Froot%3E%3C%2FmxGraphModel%3E

图3.2.6.4-1 电机控制任务工作流程

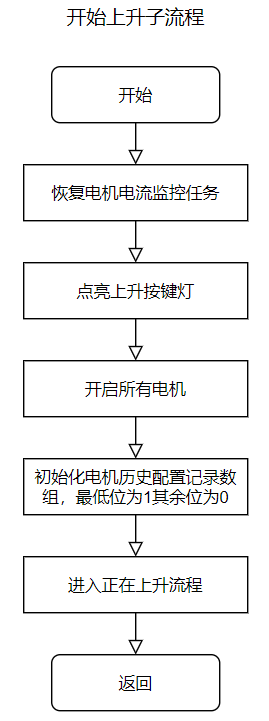


图3.2.6.4-2 电机控制任务开始上升子流程

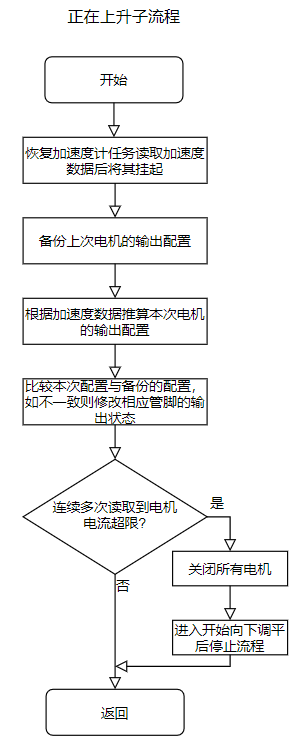


图3.2.6.4-3 电机控制任务正在上升子流程

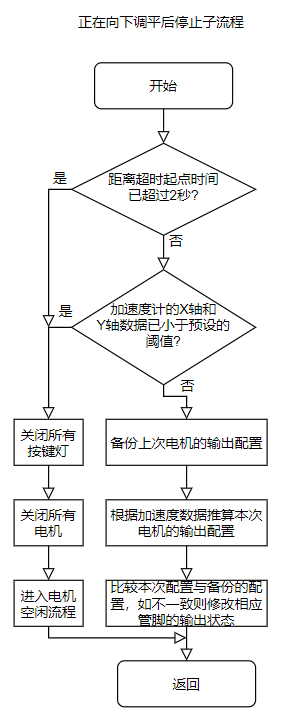


图3.2.6.4-4 电机控制任务正在向下调平后停止子流程

### 电机电流监控任务设计说明

#### 程序描述

该任务用于检测各路电机工作时的电流。

#### 功能

检测各路电机工作时的电流并将数据发送给电机控制任务供其决定是否需要采取关闭电机操作。

#### 性能

具有多点滤波功能，连续读取多次电流数据后取平均值作为输出值。

#### 程序逻辑

电机电流监控任务创建成功后自动进入挂起态，等待电机控制任务恢复才运行。任务恢复后每5ms启动一次ADC转换并等待转换完成，在采集到足够的点数后取平均值并发送至电流传感器数据消息队列供电机控制任务接收。在上升或下降操作完成后，由电机控制任务挂起电机电流监控任务从而使之再次进入挂起态。

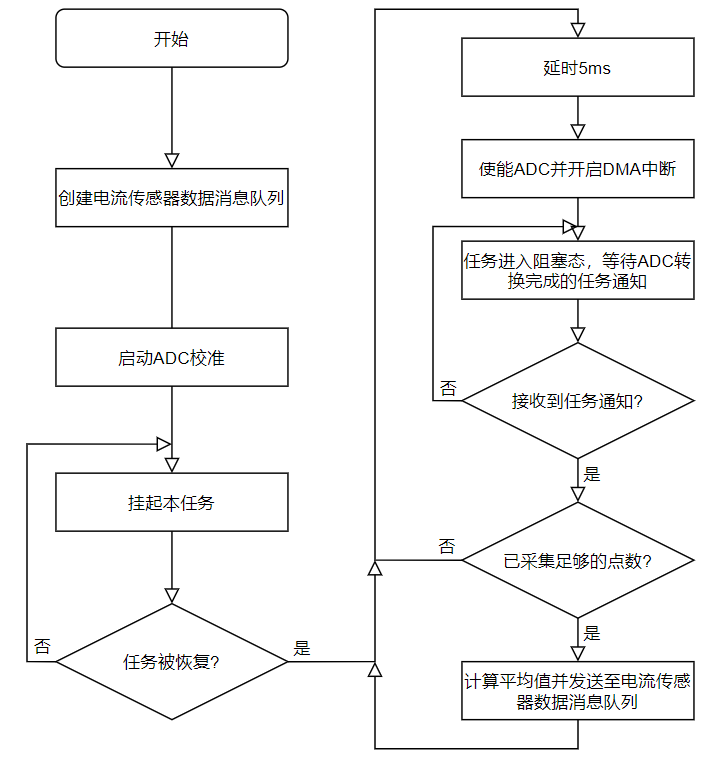


图3.2.7.4-1 电机电流监控任务工作流程

### 加速度计任务设计说明

#### 程序描述

该任务用于检测台车的平衡状态。

#### 功能

读取加速度计的X、Y、Z等各轴加速度数据并发送给串口指令处理任务或电机控制任务供其使用。

#### 性能

具有多点滤波功能，连续读取多次加速度数据后取平均值作为输出值。

#### 程序逻辑

加速度计任务创建成功后自动进入挂起态，等待串口指令处理任务或电机控制任务恢复才运行。任务恢复后每隔5ms连续读取10次加速度计数据并取平均值并发送至加速度计数据消息队列供串口指令处理任务或电机控制任务接收。串口指令处理任务或电机控制任务接收数据完成后会挂起加速度计任务使之再次进入挂起态。

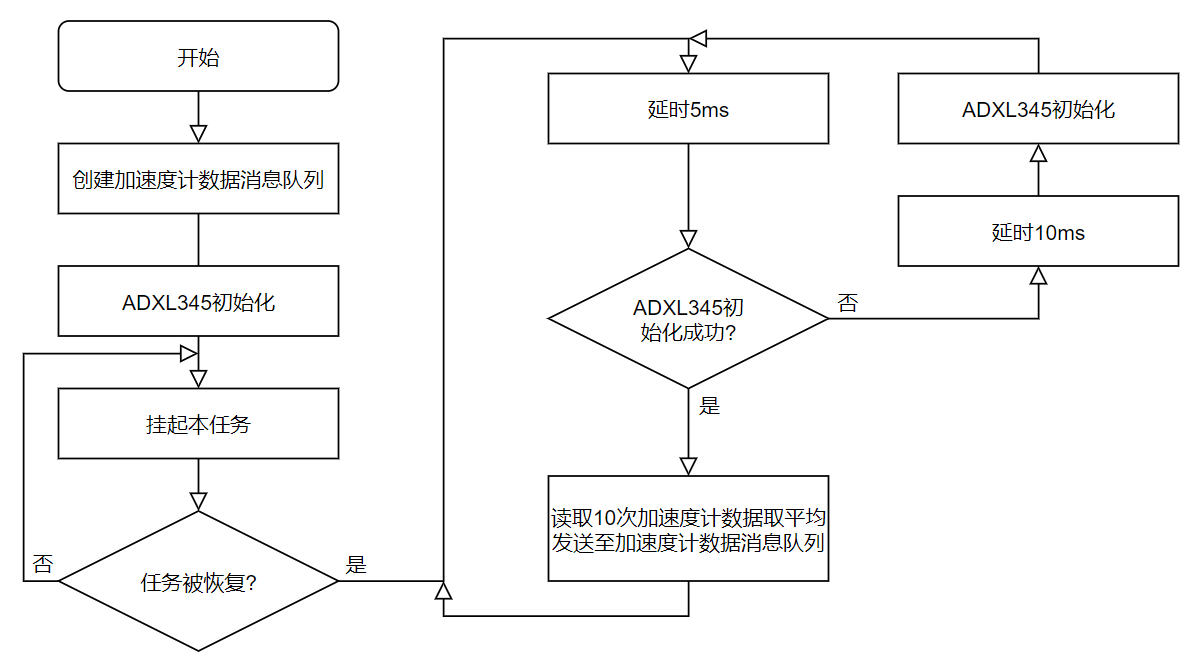


图3.2.8.4-1 加速度计任务工作流程

### 运动互锁任务设计说明

#### 程序描述

该任务用于机械臂运动与升降运动之前的互锁。

#### 功能

机械臂动作时反馈给升降控制板一个开关量信号，只要升降控制板检测到该信号则电动立柱被锁定无法运动。升降立柱动作时也会反馈一个开关量信号给机械臂。

#### 性能

程序具有消抖功能，每5ms采集一次按键信息。

#### 程序逻辑

实现过程为：系统节拍为1000Hz，故任务的执行周期为5ms。任务每执行一次扫描一次按键的状态，高电平为1，低电平为0，将每次采样到的结果按数组低位至高位分别存至16bit的数组变量。扫描16次完成后，对数组变量进行“与”操作，即可判断机械臂反馈状态并消除抖动。根据消抖后的信号判断是否锁定立柱不动作。



图3.2.9.4-1 运动互锁任务工作流程