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| **嵌入式软件详细设计说明书** | | | | | | | | |
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| 审核人： | | ？？ |  | 日期： | 2023.xx.xx | |  | |
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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－002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－002 台车控制板嵌入式软件、升降控制板嵌入式软件及末端灯光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-002，并面向项目组全体成员。

## 项目背景

MS-002导航台车包含工作站、显示器、双目相机、按钮、台车控制板以及电源。

MS-002执行台车包含UR机械臂控制箱、按钮、台车控制板、升降控制板、末端灯板、末端控制板以及电源。

MS-002操作台车包含显示器、鼠标键盘、按钮以及电源。

之前的公司项目台车的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，可以分成3个或者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：实现机械臂开关机自由拖动定位、状态指示灯光控制、升降立柱控制、UPS通讯关机等功能的线路板。

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的控制电路板。

末端灯板：实现灯光指示功能的电路板。

末端控制板：实现各部件电源控制、控制机械臂前端通道上升、下降、左旋转及右旋转和末端灯板灯光指示等功能的电路板。

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。

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

GPIO：（英语：General-purpose 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。

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

《MS-002产品技术需求规格书V1.0》

《STM32F103xC数据手册》

《STM8L101X3数据手册》

《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 | XCOM V2.6 |
| 编程工具 | ST Visual Develop V4.3.9 |
| 其他 | STM32CubeIDE V1.4.0 |

# 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－002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-002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-002产品技术需求规格书V1.0》中功能要求，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。

根据《MS-002技术需求规格书V1.0》中功能要求，需要末端控制板实现各部件电源控制、控制机械臂前端通道上升、下降、通道左旋转、右旋转和控制末端灯板等功能。末端灯板显示机械臂状态。

|  |  |  |  |
| --- | --- | --- | --- |
| **技术需求规格书-导航台车功能需求** | | | |
| **输入需**  **求序号** | **功能需求** | **实现方式** | **功能说明** |
| TR020012 | 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3.1.7状态指示灯模块设计说明 |
| TR020013 | 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3.1.7状态指示灯模块设计说明 |
| **技术需求规格书-执行台车功能需求** | | | |
| **输入需**  **求序号** | **功能需求** | **实现方式** | **功能说明** |
| TR030010 | 开关按钮：台车升、降按钮各1个（包含指示灯） | 设计控制板，实现台车升降和灯光 | 见3.1.7状态指示灯模块设计说明 |
| TR030011 | 开关按钮：通道“上升”、“下降”、“左旋”、“右旋”按钮各一个，位于机械臂法兰端 | 设计通道升降按键板，实现通道“上升”、“下降”、“左旋”、“右旋” | 见3.2.3运行灯任务设计说明 |
| TR030013 | 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3.1.6机械臂开关机模块设计说明 |
| TR030015 | 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3.1.7状态指示灯模块设计说明 |
| TR030016 | 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3.1.7状态指示灯模块设计说明 |
| TR030017 | 灯光：机械臂运行指示灯1个 | 设计末端控制板进行机械臂灯光指示 | 见3.3.4定时器模块设计说明 |
| TR030020 | 台车组成：UR5e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3.1.6机械臂开关机模块设计说明 |
| TR030021 | 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3.1.4串口模块设计说明 |
| TR030023 | 台车组成：升降机构 | 系统包含升降立柱，同时设计控制板，控制升降机构工作 | 见3.2升降控制板详细说明 |
| TR030027 | 台车组成：末端控制器：   * 设置有绝缘层用于定位器和机械臂本体间的电器隔离。 * 有灯带，用于显示机械臂工作状态。 * 有“上升”、“下降”、“左旋”、“右旋”四个按钮，控制机械臂沿着通道轴线运动。 * 有转接法兰，用于定位器的连接 | 设计末端控制器，实现此功能 | 见3.3末端控制板详细说明 |
| TR03048 | 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 |
| **技术需求规格书-非功能需求** | | | |
| **输入需**  **求序号** | **需求描述** | **实现方式** | **功能说明** |
| TR060001 | 标识、标记和文件 | 按灯光功能、供电状态定义设计控制板程序 | 见3.3末端控制板详细说明、见3.1.7状态指示灯模块设计说明 |

# 总体设计及各模块功能和框图

MS-002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-002总体框图

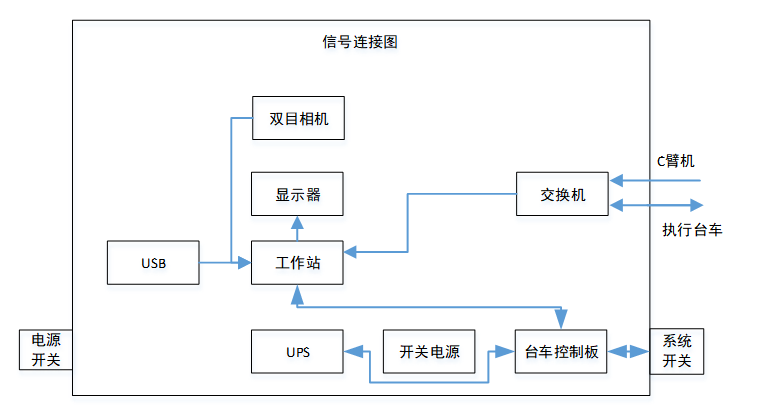


图3-2 导航台车信号连接图

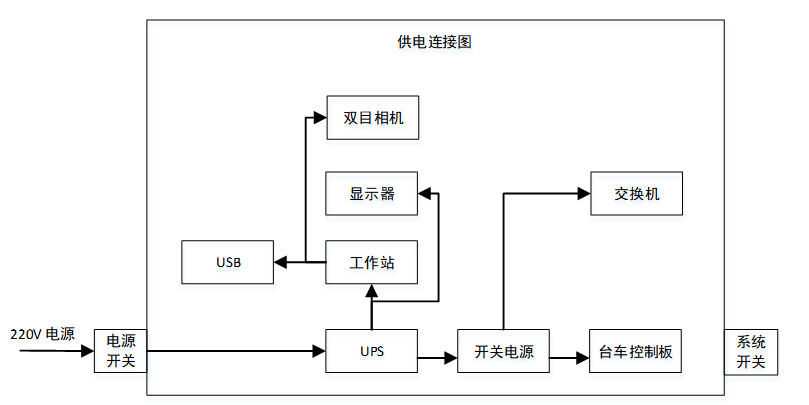


图3-3 导航台车供电连接图



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-002台车控制板集成了按键、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

工程文件目录结构如下述：

* .cproject和.project为工程文件；
* xxx.ioc为工程图形配置文件；
* 文件夹Core为核心文件，用于存放用户编写的.c和.h文件；
* 文件夹Core-Src用于存放用户编写的.c文件；

main.c主要用来编写main主函数；

stm32f10x\_it.c 主要用来定义部分中断服务函数；

system\_stm32f10x.c 主要用来定义SystemInit等系统初始化函数；

syscalls.c和sysmem.c为系统文件，无需修改；

gpio.c主要用来编写IO口初始化函数；

usart.c主要用来编写串口初始化函数；

tim.c主要用来编写定时器初始化函数；

dma.c主要用来编写DMA初始化函数；

upscom.c主要用来编写单片机与UPS通讯相关的协议函数；

key.c主要用来编写按键扫描信号检测及执行按键功能等函数；

ch375b.c主要用来编写单片机与USB芯片之间的通讯相关协议函数；

CTRL\_341.c主要用来编写USB芯片与从机之间的通讯相关协议函数；

* 文件夹Core-Inc用于存放用户编写的.h文件,主要用来编写上述各.c文件中对应的函数声明、变量声明以及宏定义。
* 文件夹Core-Startup用于存放系统启动文件，无需修改。
* 文件夹Drivers为单片机底层驱动文件，用于存放系统文件以及标准库文件；
* 文件夹Debug为工程调试输出文件。

#### 库文件说明

表3.1.1.3-1 stm32库文件

|  |  |  |
| --- | --- | --- |
| system\_stm32f10x.h  system\_stm32f10x.c | 微控制器专用系统文件 | 函数SystemInit，用来初始化微控制器  函数Sysem\_ExtMemCtl，用来配置外部存储器控制器。它位于文件startup\_stm32f10x\_xx.s /.c，在跳转到main前调用  SystemFrequncy，该值代表系统时钟频率 |
| stm32f10x.h | 微控制器专用头文件 | 这个文件包含了STM32F10x全系列所有外设寄存器的定义（寄存器的基地址和布局）、位定义、中断向量表、存储空间的地址映射等 |
| startup\_stm32f10x\_Xd.s | 编译器启动代码 | 微控制器专用的中断处理程序列表(与头文件一致)  弱定义(Weak)的中断处理程序默认函数(可以被用户代码覆盖) 该文件是与编译器相关的 |
| stm32f10x\_conf.h | 固件库配置文件 | 通过更改包含的外设头文件来选择固件库所使用的外设，在新建程序和进行功能变更之前应当首先修改对应的配置 |
| stm32f10x\_it.h  stm32f10x\_it.c | 外设中断函数文件 | 用户可以相应的加入自己的中断程序的代码，对于指向同一个中断向量的多个不同中断请求，用户可以通过判断外设的中断标志位来确定准确的中断源，执行相应的中断服务函数 |
| stm32f10x\_ppp.h  stm32f10x\_ppp.c | 外设驱动函数文件 | 包括了相关外设的初始化配置和部分功能应用函数，这部分是进行编程功能实现的重要组成部分。 |

#### 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

|  |  |  |
| --- | --- | --- |
| 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：

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

软件功能主要完成以下四个功能：

* 按键、工作站工作状态及UR机械臂工作状态检测；
* UR机械臂开关机控制；
* 与UPS通讯，串口数据解析，实现UPS延时关机等操作；
* 点亮或熄灭状态指示灯。

#### 程序逻辑

程序先执行各种初始化，然后在主循环中每50ms执行按键、信号输入扫描并置位相应标志位；每200ms执行按键对应功能以及置位相关标志位；每500ms检测UR机械臂状态标志并执行对应开关机操作；每1s与UPS通讯获取UPS当前状态。在主循环进行的同时，一直等待串口中断，若中断来临，即处理串口数据，置相应标志位。同时主循环中一直检测供电模式标志位和UPS电池标志位，并点亮或熄灭对应指示灯。



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5ms产生一次定时器中断，计时产生50ms、200ms、500ms和1s标志位，用于处理不同事件。50ms计时中断用于处理按键扫描、工作站和UR机械臂工作状态信号检测等；200ms计时中断用于处理按键事件，机械臂开关机标志位置位、自由拖动使能及工作站和UR机械臂工作状态标志位置位指示灯点亮或熄灭等；500ms计时中断用于处理UR机械臂开关机操作；1s计时中断用于处理UPS通讯获取UPS状态、自由拖动使能倒计时以及点亮或熄灭UPS电池状态指示灯和市电供电或UPS供电指示灯。

#### 程序逻辑

定时器中断程序中每5ms产生1次定时器中断，用户计数器从0开始每中断一次加1，用户计数器为10的整数倍，就置位50ms标志位；用户计数器为40的整数倍，就置位200ms标志位；用户计数器为100的整数倍，就置位500ms标志位；用户计数器大于等于200，就置位1s标志位并清除用户计数器从0开始重新计数。



图3.1.3.2-1 定时器模块程序流程图

### 串口模块设计说明

#### 程序描述

串口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50ms采集一次输入信息。

#### 程序逻辑

通过50ms标志位，每50ms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，每500ms检测一次开关机标志位并执行对应操作。

#### 性能

每500ms检测并执行，实现机械臂开关机同步化。

#### 程序逻辑

在主循环中每500ms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

在主循环中一直检测各状态标志位，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

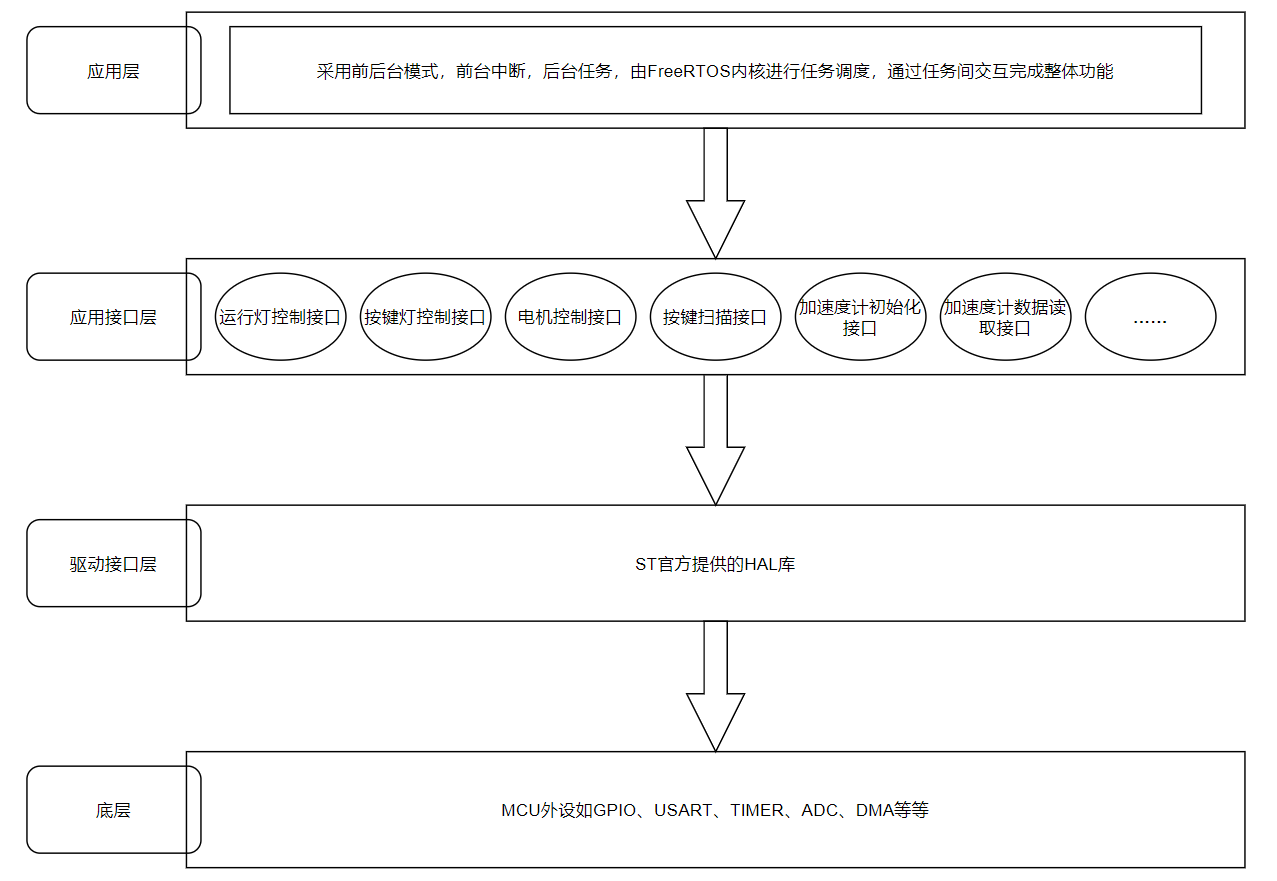


图3.2.1.1-1 系统框架

#### 代码目录结构

工程文件目录结构

1. Core - 用户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 | adc.h | 声明供外部调用的变量和函数。 |
| 2 | adc.c | 定义ADC相关变量及实现ADC初始化函数。 |
| 3 | dma.h | 声明供外部调用的函数。 |
| 4 | dma.c | 实现DMA初始化函数。 |
| 5 | gpio.h | 声明供外部调用的函数。 |
| 6 | gpio.c | 实现GPIO初始化函数。 |
| 7 | main.h | 为使用的GPIO定义别名，使之与原理图中对应。 |
| 8 | main.c | 定义main函数及时钟初始化函数等。 |
| 9 | stm32f1xx\_hal\_conf.h | 定义与硬件相关的系统参数及外设开关宏。 |
| 10 | stm32f1xx\_hal\_msp.c | 定义芯片级支持包初始化函数。 |
| 11 | stm32f1xx\_hal\_timebase\_tim.c | 定义HAL库时基初始化函数。 |
| 12 | stm32f1xx\_it.h | 声明供外部调用的函数。 |
| 13 | stm32f1xx\_it.c | 定义相关中断服务函数。 |
| 14 | system\_stm32f1xx.c | 主要用来定义SystemInit等时钟初始化函数。 |
| 15 | tim.h | 定义TIM相关变量及供外部调用的TIM初始化函数。 |
| 16 | tim.c | 实现TIM初始化函数。 |
| 17 | usart.h | 定义USART相关变量及供外部调用的USART初始化函数。 |
| 18 | usart.c | 实现USART初始化函数。 |

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

主程序主要是执行对时钟进行配置、外设初始化及相关任务的创建。

#### 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、机械臂控制箱状态检测、升降状态输出、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。

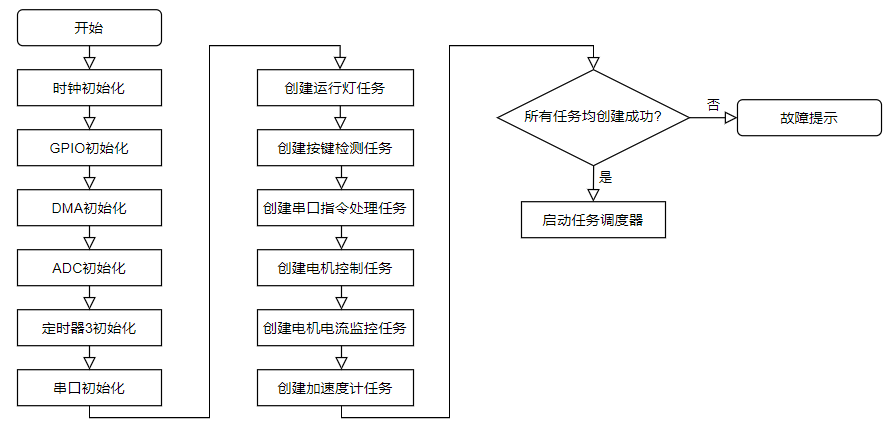


图3.2.2.2-1 主程序流程

### 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。主要用于立柱升降低控制，以及实现台车升降时，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。

#### 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200Hz，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。

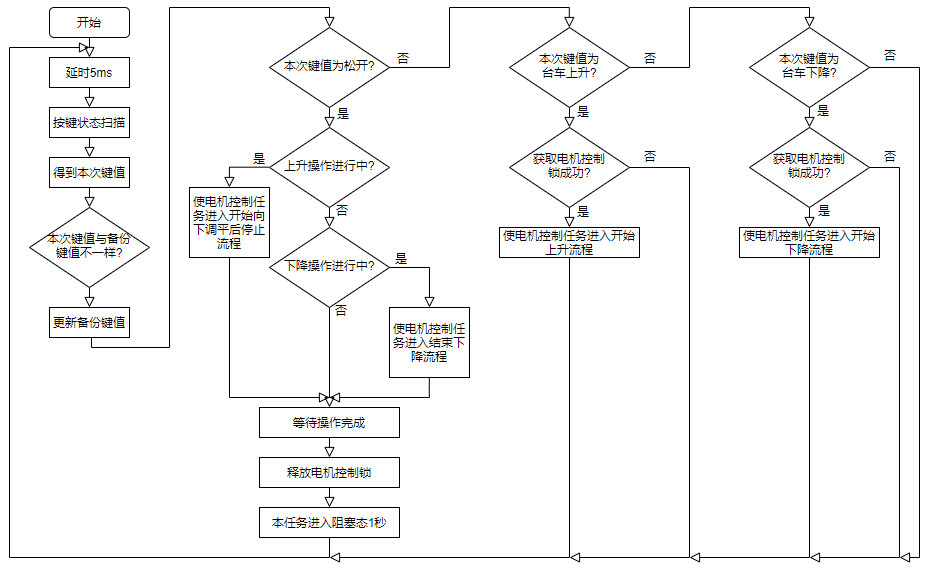


图3.2.4.4-1 按键检测任务工作流程

### 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。

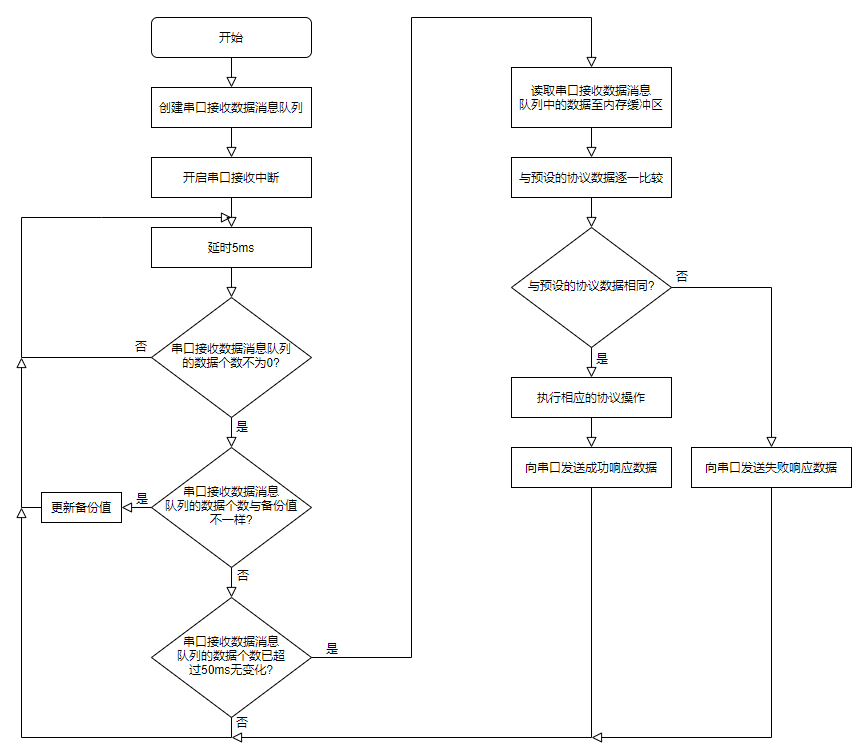


图3.2.5.4-1 串口指令处理任务工作流程

### 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。

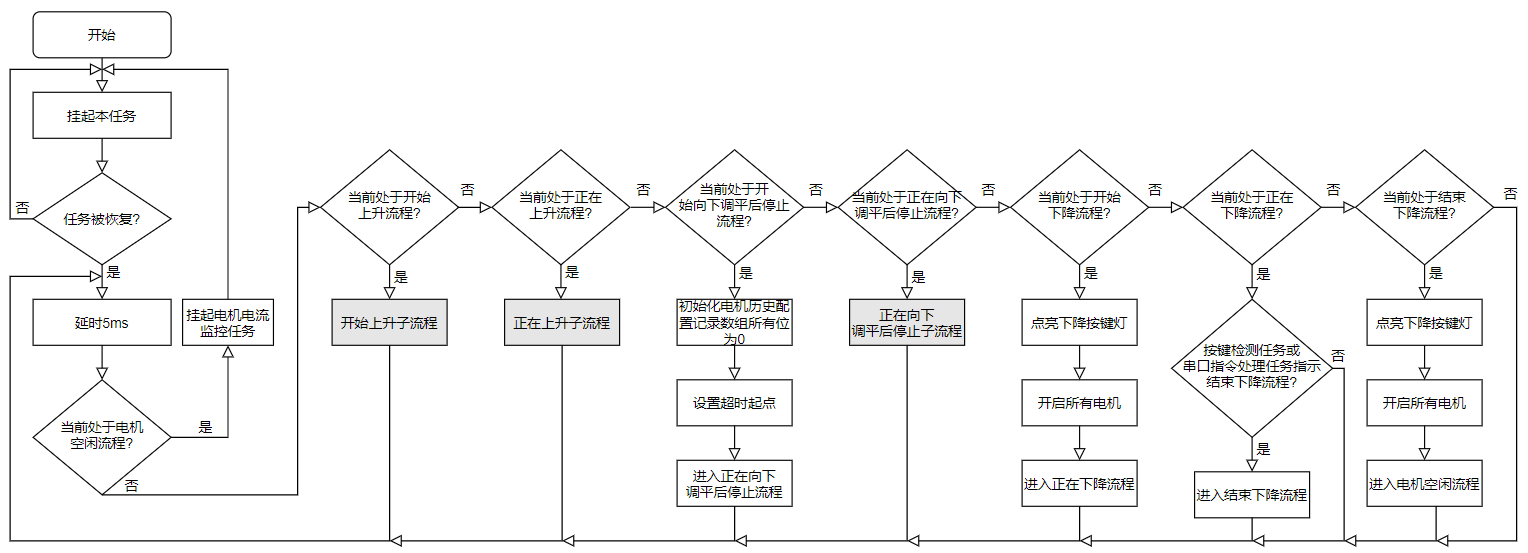
%3CmxGraphModel%3E%3Croot%3E%3CmxCell%20id%3D%220%22%2F%3E%3CmxCell%20id%3D%221%22%20parent%3D%220%22%2F%3E%3CmxCell%20id%3D%222%22%20style%3D%22edgeStyle%3DorthogonalEdgeStyle%3Brounded%3D0%3BorthogonalLoop%3D1%3BjettySize%3Dauto%3Bhtml%3D1%3BexitX%3D0.5%3BexitY%3D1%3BexitDx%3D0%3BexitDy%3D0%3BlabelBackgroundColor%3Dnone%3BendArrow%3Dblock%3BendFill%3D0%3BendSize%3D8%3B%22%20edge%3D%221%22%20source%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%20source%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%22sourcePoint%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%20source%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%22sourcePoint%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%20s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298%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%22530%22%20y%3D%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%2299%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%22730%22%20y%3D%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22100%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%22930%22%20y%3D%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22101%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%221125%22%20y%3D%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22102%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%22550%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22103%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%22860%22%20y%3D%22866%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22104%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%22447%22%20y%3D%221045%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22105%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%22850%22%20y%3D%22740%22%20width%3D%221%22%20height%3D%2210%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22106%22%20value%3D%22%E8%BF%9B%E5%85%A5%E7%BB%93%E6%9D%9F%E4%B8%8B%E9%99%8D%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%221170%22%20y%3D%22800%22%20width%3D%22140%22%20height%3D%2240%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22107%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%22330%22%20y%3D%22410%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22108%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%22640%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22109%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%22450%22%20y%3D%22636%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22110%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%22650%22%20y%3D%22637%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22111%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%22850%22%20y%3D%22640%22%20as%3D%22geometry%22%2F%3E%3C%2FmxCell%3E%3CmxCell%20id%3D%22112%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%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%22sourcePoint%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%22sourcePoint%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%22sourcePoint%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%22sourcePoint%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%22sourcePoint%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%20source%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%22sourcePoint%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%22sourcePoint%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

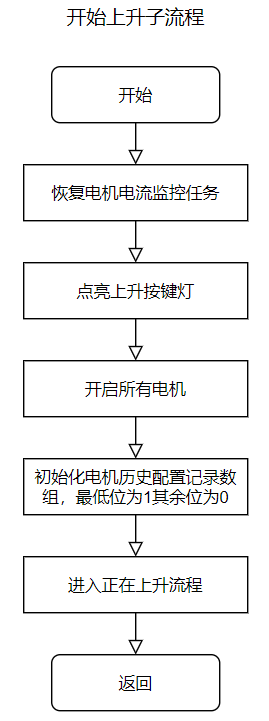


图3.2.6.4-2 电机控制任务开始上升子流程

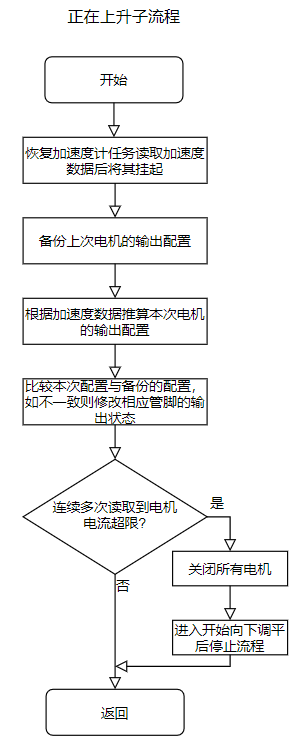


图3.2.6.4-3 电机控制任务正在上升子流程

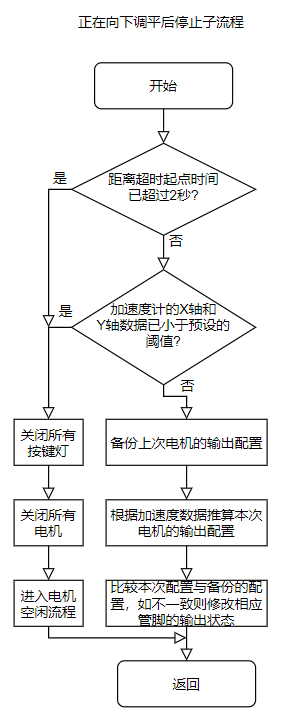


图3.2.6.4-4 电机控制任务正在向下调平后停止子流程

### 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。

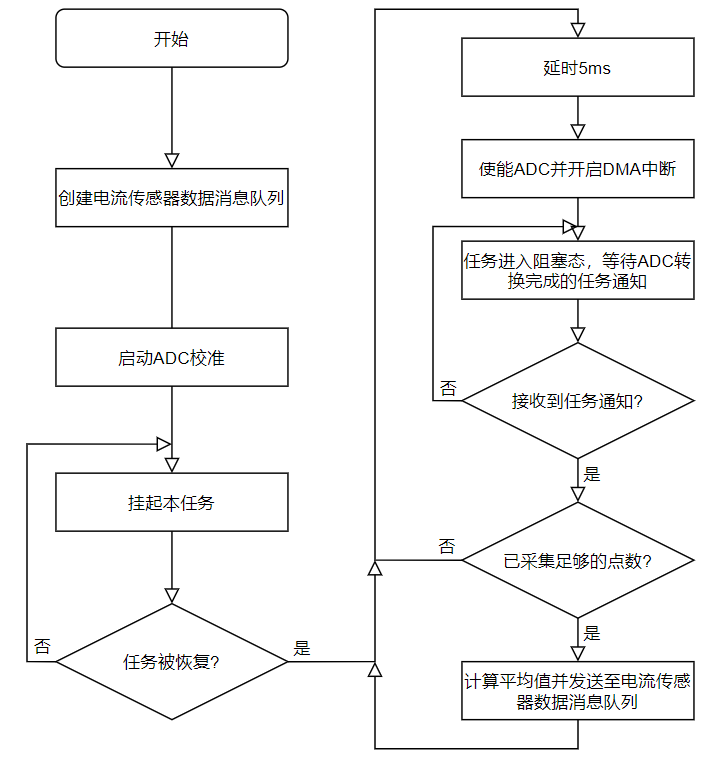


图3.2.7.4-1 电机电流监控任务工作流程

### 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。

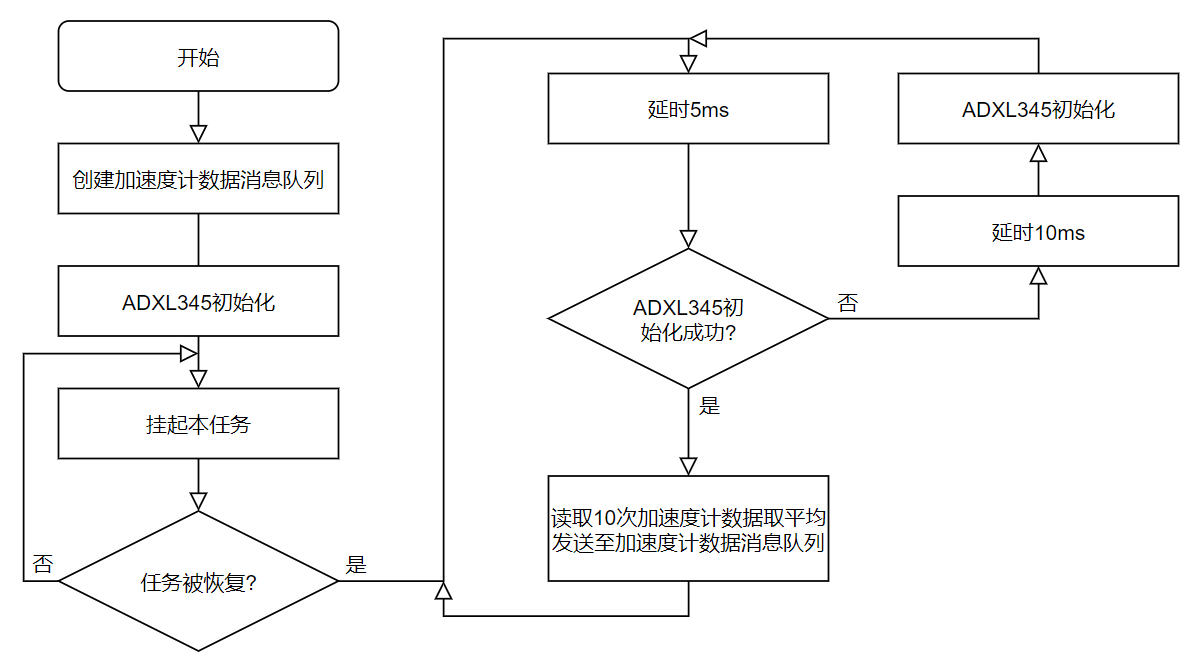


图3.2.8.4-1 加速度计任务工作流程

## 末端控制板详细说明

MS002末端控制板的软件系统包括RGB灯控制模块。末端控制板扫描机械臂工具IO口发送的状态，通过处理后RGB灯控制模块实现对三色灯控制，通过PWM脉冲调制实现颜色的切换，通过对PWM波占空比的递增或递减循环赋给PWM通道比较值实现呼吸灯操作。

### 软件结构

#### 总体框架



图3.3.1.1-1 系统框架

#### 代码目录结构

工程文件目录结构  
1、Main.c主要用来编写main主函数；

Ioscan.c 主要用来扫描机械臂工具IO状态；

Time.c 主要用来初始化定时器函数及PWM函数；

Stm8\_interrupt\_vector.c STM8中断向量表。  
2、相关的驱动函数,每个.c文件对应一个.h头文件

表3.3.1.2-1 驱动文件

|  |  |  |
| --- | --- | --- |
| Ioscan文件 | Ioscan.c | 扫描机械臂工具IO状态 |
| Ioscan.h | 定义变量读取机械臂工具IO状态、定义机械臂工具IO标志位及定义机械臂工具IO相关的函数 |
| Time文件 | Time.c | TIM2和TIM3 PWM部分初始化 ，PWM输出初始化  TIM4中断定时器初始化 |
| Time.h | 定义TIMER2、TIMER3、TIMER4 中断定时器和PWM相关的函数 |

#### 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地辨认对应的外设。如表3.3.1.3-1所示

表3.3.1.3-1 外设缩写定义

|  |  |
| --- | --- |
| 缩写 | 外设/单元 |
| GPIO | 通用输入输出 |
| TIM | 定时器 |

#### 变量类型定义

表3.3.1.4-1 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 |

### 主程序设计说明

#### 程序描述

软件功能主要完成以下两类信号处理：

* 对机械臂工具IO输出的状态进行判断，并将对应机械臂运动状态标志位置位；
* 对机械臂运动状态标志位进行判断后显示对应RGB灯状态。

#### 程序逻辑

程序主循环中首先对端口、时钟、定时器和中断使能等进行初始化，检测IO口是否存在方波后执行相应RGB灯状态，若无方波则扫描IO口判断执行其他RGB灯状态。主程序流程图如图3.3.2.2-1所示。



图3.3.2.2-1 主程序流程

### IO扫描模块设计说明

#### 程序描述

该模块是用于采集机械臂工具IO口信息，并将信息转化为相应的标志位，通过标志位表征IO口信息，设置PWM波形。

#### 功能

扫描机械臂工具IO1及IO2口，将相应状态转化为相应标志位，判断执行RGB灯状态，并在TIM4中断定时器中设置PWM呼吸状态。

#### 性能

程序具有软件消抖的功能，每100ms采集一次IO口状态信息。

#### 程序逻辑

实现过程为：通过定时器中断扫描机械臂工具IO状态，采用基本定时器通过分频得到2ms采样周期。每2ms定时器中断扫描一次机械臂工具IO的状态，高电平为1，低电平为0，每100ms连续8次出现高低电平为检测到方波。连续6次判断IO口有效输出，即可判断按键状态并消除抖动。末端控制板IO扫描模块程序框图如图3.3.3.4-1所示。

图3.3.3.4-1 输出检测程序流程图

### 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2ms产生一次定时中断，用于机械臂工具IO口扫描、RGB灯呼吸显示。

#### 功能

用于产生2ms的中断，中断服务函数通过计数产生20ms以及100ms的计时，完成RGB呼吸灯和机械臂IO口检测。

#### 性能

RGB呼吸灯变化缓慢，周期为1600ms。

#### 程序逻辑

定时器中断程序中执行按键扫描、RGB显示、机械臂按键指示灯显示、机械臂开关机信号控制、UR&PC状态信号等后台事件。定时器周期设置为5ms，每5ms产生1次定时器中断，机械臂工具IO被扫描一次，相应的计时变量加累加1，并判断变量这些是否满足目标值。当满足目标值时，变量清零，并执行对应的事件。其中包括RGB灯状态切换事件。定时器流程图如图5.4-1所示。



图3.3.4.4-1 定时器工作流程图