

# **Home Automation**

# **Home Automation - Weather Clock**

## Introduction

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This user guide presents a *Weather Clock* design using the AVR<sup>®</sup> IoT WG Board. The weather clock fetches forecast data for a physical location and presents it to the user as a position on the clock. See Figure 1 for a photo of the clock on a sunny day.

Most of the design complexity resides in the cloud, and will be the focus of this user guide. The weather clock uses the Google Cloud Platform (GCP) as the cloud provider. Topics covered are:

- Fetching and storing weather data from yr.no
- · Converting weather data to clock hand position
- Adding precise stepping functionality to the stepper motor driver on the AVR-IoT WG Board
- · Automating the process using a cloud scheduler



**Tip:** It is recommended that the reader has read the preliminary *"Getting started with the AVR Home Automation Kit"*. It can be found at http://www.microchip.com/DS50002957.



**Tip:** The embedded source code for the weather clock can be found at <a href="https://start.atmel.com/#examples">https://start.atmel.com/#examples</a> under the name "AVR IoT WG Sensor Node with Stepper 2 Click". Under "Example Configuration", select "WEATHER CLOCK".

#### Figure 1. A Photo a Finished Weather Clock



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# 1. Connecting Devices to the Cloud

Cloud modules used in this section



For IoT devices, the cloud is a remote platform that can be used to offload tasks such as computing, storage and communications. The big difference between a traditional server solution and the cloud is the *serverless* aspect. When working with cloud solutions, the servers and virtual machines are abstracted away. Instead, everything *lives* in the cloud, where the engineer only works on the solution without worrying about the underlying infrastructure.

The weather clock uses the **Google Cloud Platform**. At the time of writing, the free tier covers every requirement for the weather clock. The cloud service is configured through either its online *console* GUI or the command line argument utility *gcloud*. This user guide uses the online console GUI to configure all cloud modules.

The Google Cloud is divided into several modules based on your needs. The weather clock uses the modules given in Table 1-1. Each module has a specific purpose, allowing powerful functionality by making different modules interact.

Module Name	Description	Documentation
IoT Core	Connect and manage IoT devices. Sends and Receives data, handles authentication.	https://cloud.google.com/iot-core/
Functions	Serverless functions which live in the cloud. Triggers based on events, such as an HTTP request or MQTT message.	https://cloud.google.com/functions/
Storage	Store and fetch files.	https://cloud.google.com/storage/
Scheduler	A fully managed cron job scheduler. Allows for automation in the cloud.	https://cloud.google.com/scheduler/

Table 1-1.	<b>Cloud Modules</b>	Used by the	Weather Clock
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## 1.1 Configuring IoT Core



**Tip:** If you do not have a Google Cloud account, you can obtain one at https://console.cloud.google.com/ freetrial.

The IoT Core module is designed to handle all communications with IoT devices. All devices are registered in the IoT Core with a unique ID and authentication credentials. In short, it serves as a *gateway* between the IoT devices and the rest of the cloud.

Google Cloud requires that all functionality belongs to a project. The weather clock uses the project name **iot-weather-clock**. The IoT Core module can be opened through the menu at the left-hand side of the cloud console. Click "Enable" to add the module to the cloud project. When the IoT Core is added, a *Registries* page should appear. See Figure 1-1 for screenshots of the procedure.

=	Google Cloud Plat	tform	2			
			9		Google C	loud IoT API
•	Home				Google	
đb	IoT Core				Registers and n to the Google C	nanages IoT (Internet of Things) devices that conne loud Platform.
*?*	101 0016					
*	Pub/Sub	>			ENABLE	TRY THIS API
(…)	Cloud Functions					
	Storage	>	ណិ	oT Core	Pagistrias	
බ	Cloud Scheduler		979	UT COLE	Registiles	GREATE REDISTRY
ത്	Cloud Scheduler		₹ Filte	er registries		3

Figure 1-1. How to Find the IoT Core Module

To connect a device to the IoT Core Module, it must be added to a registry. A registry is a set of devices that can communicate with the cloud. To create a new registry, click the **Create Registry** button. There are several required fields. Configure the weather clock registry according to the "Entry" column in Table 1-2. Some fields might not appear before clicking "Show Advanced Options".

Name	Entry	Description
Registry ID	weather-clock-devices	A permanent ID which identifies the registry
Region	The region which is applicable	The geographical region where the data are stored
Protocol	✓ MQTT □ HTTP	Which communications protocol does the registry support? Both MQTT and HTTP are supported.
Cloud Pub/Sub topics	Select the dropdown menu and select <b>Create a topic</b> . Enter the topic name <i>weather-upstream</i> . Leave the rest as default and press "Create topic".	The default telemetry topic is the MQTT topic, which all messages from the device are routed to.
Device state topic (optional)	Leave unchanged	All state events published by the device is sent there. Not used by the weather clock.
Stackdriver Logging	None	Not used by the weather clock

#### 1.1.1 Adding a Device to the Registry

All devices in a registry are found by selecting the *devices* tab on the left-hand side. A new device can be added by pressing **Create a Device**. See Figure 1-3. To add the AVR IoT WG board, leave everything as default except "Device ID", "Public Key Format" and "Public key value". The *Device ID* is found in the URL of the "CLICK-ME.htm" file. The "CLICK-ME.html" file is located under the "CURIOSITY" drive when the kit is connected through USB, see the example in Figure 1-2. Google Cloud requires the first character to be a letter. The entered Device ID should thus be "d + the number". For instance "d0123710B94CEB0ECFE".

#### Figure 1-2. Finding the Device ID for the IoT Board

https://avr-iot.com/device/0123710B94CEB0ECFE

rigure 1-5. Adding a New Device to the for Core Registry						
≡	Google Cloud Platform	• iot-weather-clock ▼				
	IoT Core	Devices + CREATE A DEVICE TO DELETE				
⊞	Registry details	Registry ID: weather-devices				
0	Devices	europe-west1				
	Gateways	Devices are things that connect to the internet directly or through a gateway. Learn more				
ай	Monitoring	= Enter exact device ID				
		Device ID Communication Last seen Stackdriver Logging				
		No devices to display in this registry				
		Cloud IoT Core documentation				

#### Figure 1-3. Adding a New Device to the IoT Core Registry

The public key format is "ES256". The public key is found in the "PUBKEY.txt" file under the CURIOSITY drive. Copy the contents in the public key value field. The details should be similar to Figure 1-4. Click "Create" to add the device.

Figure 1-4. Device Settings for the AVR® IoT WG Board

Device ID 🔞	
d0123710B94CEB0ECFE	
Public key format	
○ RS256 Ø	
ES256 (2)	
RS256_X509 (2)	
ES256_X509 (2)	
Public key value	
BEGIN PUBLIC KEY MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEBNyVKPHSfaF5S3FA/84KtIJiQvyV Fg16S/ <u>TtQQwjnx</u> /JnmYquwjT6xpakQjTWtdQXFaBU10TFY8KMpFmgJGGWQ== END PUBLIC KEY	

# 2. Fetching and Storing Weather Data



The weather clock requires up-to-date weather data to function. The data must be fetched, cached, parsed and converted to a clock hand position at a regular interval. Such a task is not handled by the device itself but by the cloud. This section explains how the cloud is configured and programmed to handle the given task. A block diagram of the finished solution can be seen in Figure 2-1.

The weather data is provided by YR.no, a free and open weather service from the Norwegian Meteorological Institute. At a regular interval, the weather data is downloaded from YR.no and stored using **Google Cloud Storage**. The downloading, parsing and converting is done by a python script through a **Cloud Function**. A cloud function is a snippet of code that is *serverless* (no dedicated resources, see Google's documentation), running when a *trigger* event occurs.



**Tip:** For more information on YR.no's API, see https://hjelp.yr.no/hc/en-us/articles/360001940793-Free-weather-data-service-from-Yr.

#### Figure 2-1. Block Diagram of the Finished Solution



## 2.1 Creating Persistent Storage

YR.no's API can only be accessed once every 30 minutes for one weather location. To handle this limitation, storage is introduced. As the cloud is serverless, some storage must be allocated to cache the data. Storage can be allocated through the *storage* module, creating *buckets* of data.

A bucket is created by navigating to the Storage module and clicking **Create bucket**. The bucket name is *globally unique* and is accessible by all projects on the platform (as long as they are authenticated). For the weather clock, every parameter can be left at their default values.

## 2.2 Uploading Source Code

A cloud function runs some source code whenever it is triggered. Source code can be uploaded to the Google Cloud through the "Source Repositories" module, which, in essence, is a git implementation. Google Cloud can connect to two external git providers, one of them being GitHub. The complete source code for processing the weather data can be found at https://github.com/microchip-pic-avr-solutions/avr-home-automation-weather-clock-cloud. By *forking* the repository to a personal GitHub account, it can be connected to gcloud, and device-specific configuration can be added. For more information on how to fork a GitHub repository, see GitHub.com.

A new source repository can be connected by navigating to the cloud source repositories module and clicking **Add Repository** in the upper right-hand corner, followed by *Connect external repository*. Select the project created earlier under "Project" and GitHub as the "Git provider". When selecting GitHub as the git provider, the forked repository should appear in the list. After selecting it and pressing **Connect selected repository**, it should appear as a repository in the cloud source repositories.



Tip: Git is a popular version control system. To learn more, see https://try.github.io/.



**Tip:** (*This tip assumes intermediate git knowledge.*) It is not necessary to connect to a GitHub account. Instead of "Connect external repository", a new repository can be created. Clone the provided GitHub repository, and change the remote on the cloned local repository. By using a force push, it can be pushed directly to the gcloud source repository.

## 2.3 Configuring the Source Code

Some configurations must be added to the source code for it to work properly with a given device. Navigate to the forked repository on GitHub, select the *config.py* file list followed by the *Edit Code* button (the pen icon). This allows the content of config.py to be modified. A screenshot can be seen in Figure 2-2.

Figure 2-2. How to Edit config.py

📄 .gitignore	Initial working version					15 d	ays ago
README.md	Added readme					1 he	our ago
🖹 config.py	Added string conversion before return					2 ho	urs ago
🖹 main.py	Added string conversion before return					2 ho	urs ago
requirements.txt	Added string conversion before return					4 d	ays ago
36 lines (31 sloc)   1.71 KB		Raw	Blame	History	Ģ	1	Î
1 # (c) 2019 Microchip T	echnology Inc. and its subsidiaries.					1	
3 # Subject to your compliance with these terms, you may use this software and			- 1				
4 # any derivatives exclusively with Microchip products. It is your responsibility							

- 5 # to comply with third party license terms applicable to your use of third party

There are eight fields to be configured. Each field is explained in Table 2-1. When the correct settings are entered, the changes can be applied by pressing the *Commit Changes* button.

Name	Default entries	Description
PROJECT_ID	iot-weather-clock	The project ID of the gcloud project
IOT_CORE_REGION	europe-west1	The IoT Core region
IOT_CORE_REGISTRY_ID	weather-devices	The ID of the IoT Core configured in 1.1 Configuring IoT Core
IOT_CORE_DEVICE_ID	d0123710B94CEB0ECFE	The Device ID registered in 1.1.1 Adding a Device to the Registry
YR_LOCATION_URL	https://www.yr.no/place/ United_Kingdom/England/London/ forecast.xml	The YR.no API URL to fetch the weather data from. More info can be found at https://hjelp.yr.no/hc/en-us/articles/360009342913-XML-specification-of-forecast-xml.
CLOUD_STORAGE_BUCKET_ID	weather-clock-cache	The ID of the storage bucket created in 2.1 Creating Persistent Storage
TEMP_MAX	15	The temperature which maximizes the clock hand
TEMP_MIN	-5	The temperature which minimizes the clock hand

#### Table 2-1. Source Code Config Fields

## 2.4 Creating a Cloud Function

A **Cloud Function** must be created to make the uploaded source code run at a given trigger. A cloud function is created by navigating to the Cloud Functions module and clicking **Create Function**. When creating a function, there are several required fields. Leave everything at default except for the fields shown in Table 2-2. When the cloud function has been created, it can be invoked by opening the *trigger URL*, found under the "trigger" tab of the newly created cloud function. A screenshot is shown in Figure 2-3.

Table	2-2	Cloud	Function	Fields
lable	2-2.	olouu	i unction	i icius

Name	Entry	Description
Name	weather	A name to identify the cloud function
Trigger	НТТР	Which event type should trigger the cloud function to run
Authentication	Unchecked: Disallow unauthenticated requests.	By not checking this box, triggers must be authenticated with the cloud for it to run
Source Code	Cloud Source repository	The location the source code is located
Runtime	Python 3.7	The programming language the code is written in
Repository	github_your_username_yr-weather- fetcher	The name of the repository the code is located at. This is the name of the repository created in 2.2 Uploading Source Code.
Function to excute	fetch_process_send	The entry point of the source code

# Home Automation

**Fetching and Storing Weather Data** 

(···) o	loud Fu	nctions		÷	Function details	
🥑 wea	ther					
Version	5, deployed	at Sep 27, 2	019, 12:31:0	7 PM 👻		
General	Trigger	Source	Testing			
Trigger ty HTTP	be					
UDI						



**Tip:** If changes are made to the source code, the changes are not propagated to the cloud function unless it is redeployed. To redeploy a cloud function, open it, select *edit* followed by *deploy*.

## 2.5 Running on a Schedule

To make the cloud fetch and process the weather data regularly, the **Cloud Scheduler** module is used to make the cloud function run on a thirty-minute interval. To create a new cloud scheduler *job* (task), navigate to the cloud scheduler module, and select *Create Job*. Each required field is described in Table 2-3. When the scheduler has been configured, the cloud function created in 2.4 Creating a Cloud Function should be called every 30 minutes, sending up-to-date weather data to the device.



**Tip:** If the reader is familiar with Linux<sup>®</sup> systems, one should find that the cloud scheduler in its simplest form is a cron job manager, a widely used scheduler found in many Linux systems.

#### Table 2-3. Cloud Scheduler Fields

Name	Entry	Description
Name	weather-scheduler	A unique name identifying the job
Frequency	*/30 * * * *	A schedule in the unix-cron format. The default entry runs every 30 minutes. See https:// cloud.google.com/scheduler/docs/ configuring/cron-job- schedules#defining_the_job_schedul e for more information.

continued						
Name	Entry	Description				
Timezone	Greenwich Mean Time (GMT)	The timezone which the scheduler runs in. Depending on the frequency entry, the timezone can affect when it triggers.				
Target	HTTP	When the scheduler triggers, it calls this target				
URL	https://us-central1-iot-weather- clock.cloudfunctions.net/weather	The <i>trigger URL</i> of the cloud function created in 2.4 Creating a Cloud Function				

## 2.6 Configuring Authentication



**Important:** This section is not necessary to understand to make the weather clock function. It is, however, recommended as a live setup would most likely require this level of security. If this section is skipped, anyone can invoke the cloud function and update the weather clocks position.

With the default settings, anyone with the trigger URL of the cloud function can start code execution. **Service Accounts** solve this authentication task and are Google's method of handling permissions in the cloud. A service account has specific permissions, such as *Invoke Cloud Function* and *Run Scheduler Job*. Cloud modules can be configured to only allow specific service accounts to access them. A thorough explanation of these service accounts can be found here: https://cloud.google.com/iam/docs/understanding-service-accounts.

To only allow the *weather-scheduler* job to invoke the *weather* cloud function, create a new service account. This is done by navigating to the "IAM & admin" module. Select "Service Accounts" on the left-hand side menu. Click "Create Service Account". The weather clock entries are shown in Table 2-4.

Name	Entry	Description
Service Account Name	weather-service	A display name for the service
Service account ID	weather-service	A unique identifier for the service account. Also known as the <b>Service Account Email</b> .
Service account description	Service account to invoke cloud functions with the cloud scheduler	-

#### Table 2-4. Weather Service Account Fields

When pressing continue, the cloud prompts for which *service account permissions* to add. The weather clock requires the following permissions.

- Cloud Scheduler Job Runner
- Cloud Functions Invoker

When the service account has been created, it appears in the service accounts table. The *email* field uniquely identifies each service account and is used to allocate permissions. The *cloud functions* and *cloud scheduler* modules must be configured to only allow the weather-service account to access them. At the cloud functions page, permission members can be added and removed by checking the checkbox to the left of the cloud function name, opening the permission panel on the right-hand side. See Figure 2-4 for a screenshot. By default, the *allUsers* group has permission to invoke. The *allUsers* permission is removed by clicking the trash can icon, removing the ability for anyone to invoke the function.

# Home Automation Fetching and Storing Weather Data



#### Figure 2-4. Cloud Function Permission Settings

To permit a service account to invoke the function, click the **Add Member** button, opening an "*Add Members*" dialog. The "*New Members*" field selects which service account to gain permission. Enter the service account email created in the previous step. By selecting the role to be *Cloud Functions Invoker*, the given service account will be given permissions to run the cloud function. See Figure 2-5 for a screenshot.

#### Figure 2-5. Adding Weather Service as a Member to the Weather Cloud Function

# Add members and roles for "weather" resource Enter one or more members below. Then select a role for these members to grant them access to your resources. Multiple roles allowed. Learn more New members weather-service@iot-weather-clock.iam.gserviceaccount.com

With the above configuration, all HTTP triggers must be authenticated with the weather-service accounts credentials. The cloud scheduler must be configured to use these credentials to invoke the cloud function. These are added by editing the cloud scheduling job in the scheduler module and filling in the information given in Table 2-5 (press *Show More* to see these fields).

#### Table 2-5. Cloud Scheduler Authentication Fields

Name	Entry	Description
Auth header	Add OIDC Token	How the HTTP request is authenticated. For a service account, this is usually OIDC.
Service Account	Example entry:weather-service@iot- weather- clock.iam.gserviceaccount.com	Which service accounts credentials are sent. Must be a service account that has cloud function invoking rights.
Audience	<i>Example entry:</i> https://us-central1- iot-weather-clock.cloudfunctions.net/ weather	Auto filled

# 3. Setting up the IoT Board

**Important:** The concepts and source code discussed in this section heavily rely on the source code discussed in the *Getting Started with the Home Automation Kit document*. It can be read here: http://www.microchip.com/DS50002957.

**Important:** The complete source code for the firmware can be found at https://start.atmel.com/#examples under the name "AVR IoT WG Sensor Node with Stepper 2 Click". Under "Example Configuration", select "WEATHER CLOCK". If there is no desire to understand how the firmware and drivers function, this section can be skipped.

The IoT Board code from the Getting Started guide (http://www.microchip.com/DS50002957) must be modified slightly to become a weather clock. The following section expands the motor driver to do precise stepping and implements cloud communication to receive weather forecast data.

The starting point for the source which is expanded upon in this section can be obtained from Atmel START (https:// start.atmel.com/#examples) under the name "AVR IoT WG Sensor Node with Stepper 2 Click". Select "BASIC\_MOTOR\_CONTROL" under "Example Configuration".

## 3.1 Expanding the Motor Driver: Precise Stepping

Precision is one of the major advantages of a stepper motor. For every step, the number of degrees rotated is known exactly. Due to this unique property, the motor can be controlled in an **open loop**. This implies that there is no need for any sensors to track the motor's position, as the position can always be deducted as long as the starting position is known.

Every stepper motor has a **Step Angle** corresponding to the number of degrees the motor rotates for every pulse. The number of steps to send to move the motor by a given angle is found by Equation 3-1. The following code is a simple method to step precisely:

#### Equation 3-1. Number of Steps to Move the Motor a Given Angle

$$#steps = \frac{angle}{STEP \ ANGLE}$$

```
uint16_t number_of_steps = degrees_to_step / STEP_ANGLE;
// For all steps, do one pulse
for(uint16_t i = 0; i < number_of_steps; i++) {
    MOTOR_ST_toggle_level();
    _delay_ms(1);
    MOTOR_ST_toggle_level();
    _delay_ms(1);
}
```

The Adafruit Stepper Motor found in the Home Automation Kit has a step angle of 1.8°, giving  $\frac{360}{1.8} = 200$  possible

positions for the stepper motor. The weather clock receives a clock hand position between zero and 200. Depending on the current position of the clock hand, the motor must rotate either clockwise (CW) or counter-clockwise (CCW). The motor should rotate in the direction with the shortest distance. The two distances can be calculated as shown in Equation 3-2.

#### Equation 3-2. Distance Calculations for Clock Hand Travel

CCW = (current\_position - target\_position) % 200

*CW* = (targ*et\_position* - *current\_position*) % 200

The percentage sign (%) implies a modulo operation, as a circle operates with 360 modular arithmetic. However, there are only 200 possible states, hence modulo 200 instead of 360. For instance, the summation  $190 + 20 \rightarrow 10$ .

Any position above 200 can be converted to the equivalent position under 200 by a modulo 200 operation (position % 200).

When the shortest distance in both the CW and CCW direction has been calculated, the motor rotates the appropriate number of degrees by the shortest path. The current position is updated when the motor has rotated. The following code implements this:

```
// Calculate clockwise and counter clockwise distance
int16 t counter_clockwise = MATH_MODULO(current_position - target_position, 200);
int16_t clockwise = MATH_MODULO(target_position - current_position, 200);
// How many steps (and in which direction) do we have to turn to reach target_position?
uint16_t number_of_steps = 0;
if(clockwise < counter_clockwise){
    motor_set_direction(MOTOR_DIRECTION_CLOCKWISE);
    number_of_steps = clockwise;
    current_position = MATH_MODULO(current_position + number_of_steps, 200);
}else{
    motor_set_direction(MOTOR_DIRECTION_COUNTER_CLOCKWISE);
    number_of_steps = counter_clockwise;
    current_position = MATH_MODULO(current_position - number_of_steps, 200);
}
```



**Tip:** MATH\_MODULO refers to using the mathematical definition of modulo and not the C version of modulo, which is different. The exact definition of MATH\_MODULO is #define MATH\_MODULO(n,M) (((n % M) + M) % M).

### 3.2 Cloud Communication

As weather data becomes available, the cloud configuration from 2. Fetching and Storing Weather Data sends a *position* MQTT message to the board, which represents the clock hand position. The handling and decoding of this "*position*" message are the same as the *speed* messages in the Getting Started Guide (http://www.microchip.com/DS50002957) but calling the *motor\_goto\_position(position)* instead.

```
if(*endptr == '\0'){
    // Successful conversion of the entire string. Set position
    debug_printer(SEVERITY_NONE, LEVEL_NORMAL, "Setting position %d \n", position);
    motor_goto_position(position);
}
```

By default, the firmware is linked to the example project in Google Cloud and must be changed to the cloud project created earlier in this user guide. This is done by reconfiguring the Atmel START project. In Atmel Studio, right-click the project in the solution explorer. Select "Re-Configure Atmel Start Project". See Figure 3-1 for a screenshot.

Figure 3-1.	gure 3-1. Reconfiguring Atmel START						
	💽 So	oluti	on 'A	VR IoT WG Sensor Node With Stepper 2 (	Click' (1 pro	oject)	
			÷	Build Rebuild Clean			l
			•	Copy Full Path Collapse			
	۵ ۵			Scope to This New Solution Explorer View			
				Add	•		
	Þ	C	8 <b>0</b>	Add Library			
			₽	Set as StartUp Project			
	Þ		00	Add Arduino Library			
	Þ	Е	<b>8</b> 6	Re-Configure Atmel Start Project			
	Þ			View Project Snapshots			
		h		Take Snapshot			
		C		View Example Project Help	•		
		h		Export Project as Extension			
		C	ጽ	Cut	Ctrl+X		
		h	×	Remove	Del		
		C	<u>x</u>	Rename	F2		
		h	-	Unload Project			
		C	۷	Properties			
		h	sens	sors handling.h			•

The settings for which cloud project to connect to can be changed by clicking the AVR IoT WG Sensor Node box. All the details can be entered in the "Cloud Configuration" table. Edit Project ID, Project Region, and Registry ID to the respective values from section 1. Connecting Devices to the Cloud. Leave MQTT Host at default. See Figure 3-2 for a screenshot. When clicking "Generate Project", these new settings are saved to the source code.

#### Figure 3-2. Cloud Configuration in Atmel START

CLOUD CONFIGURATION					
project id:	0	iot-weather-clock			
project region:	0	europe-west1			
registry id:	0	weather-devices			
mqtt host:	0	mqtt.googleapis.com			

# 4. Revision History

Doc. Rev.	Date	Comments
A	02/2020	Initial document release

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# Microchip Devices Code Protection Feature

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Austin, TX         Tel: 86-571-8792-8115         Tel: 82-254-7200         German - Hean           Tel: 512-257-3370         China - Hong Kong SAR         Halaysia - Kuala Lumpur         Tel: 49-2129-37664/00           Boston         Tel: 82-2594-5100         Heimony - Heimony         Germany - Heimonn           Tel: 774-760-0087         China - Nanjing         Malaysia - Penang         Tel: 49-7131-72400           Fax: 774-760-0088         China - Gingdao         Philippines - Manila         Tel: 49-721-825370           Chicago         Tel: 86-528-4502-7355         Tel: 60-4227-887         Germany - Karisruhe           Fax: 30-285-0071         Tel: 86-521-3328-8000         Tel: 80-89-827-144-0         Fax: 49-89-827-144-0           Fax: 63-0285-0075         China - Shenzhen         Tel: 80-89-827-144-0         Fax: 49-89-827-144-0           Fax: 63-0285-0075         China - Shenzhen         Tel: 80-80-371-8306         Tel: 49-8031-364-630           Dallas         Tel: 66-24-234-2802         Tel: 80-71-87306         Tel: 49-8031-364-630           Tel: 972-818-2024         China - Suzhou         Tel: 80-72-178-306         Tel: 49-8031-742-714           Tel: 972-814-702         Tel: 80-72-97-44-7705         Tel: 39-931-742611         Tel: 972-9-74-47705           Tel: 972-814-7203         Tel: 80-72-37800         Tel: 49-8033-1466781 <td< td=""><td>Fax: 678-957-1455</td><td>China - Hangzhou</td><td>Korea - Seoul</td><td>Tel: 49-8931-9700</td></td<>	Fax: 678-957-1455	China - Hangzhou	Korea - Seoul	Tel: 49-8931-9700
Tel: 512-257-3370       China - Hong Kong SAR       Malaysia - Kuala Lumpur       Tel: 49-2129-3766400         Boston       Tel: 82-2943-5100       Tel: 60-37651-7906       Germany - Heilbronn         Westborough, MA       China - Nanjing       Malaysia - Penang       Tel: 49-7137-2400         Tel: 747-760-0087       Tel: 80-25-8473-2460       Tel: 60-4227-8870       Germany - Marisruhe         Fax: 774-760-0088       China - Shanghal       Singapore       Tel: 49-89627-144-40         Tel: 60-328-6007.50       China - Shanghal       Singapore       Tel: 49-89627-144-40         Fax: 630-285-0075       China - Shanghal       Singapore       Tel: 49-896327-144-40         Fax: 630-285-0075       China - Shanghan       Tel: 86-367-3366       Tel: 49-89637-144-40         Fax: 630-285-0075       China - Shanghan       Tel: 86-367-3366       Tel: 49-89637-144-40         Fax: 630-285-0075       China - Shanghan       Tel: 86-37-137830       Tel: 97-29-744-705         Fax: 97-2818-7292       China - Shanghan       Tel: 868-2013-773830       Tel: 99-031-742611         Detroit       Tel: 86-25361-7356       Tel: 868-208-8000       Tel: 99-031-742611         Novi, M       China - Xian       Taliand - Bangkok       Fax: 39-043-742611         Novi, M       Tel: 86-25964-1351       Tel: 89-031-46671 <td>Austin, TX</td> <td>Tel: 86-571-8792-8115</td> <td>Tel: 82-2-554-7200</td> <td>Germany - Haan</td>	Austin, TX	Tel: 86-571-8792-8115	Tel: 82-2-554-7200	Germany - Haan
Boston         Tel: 852-2943-5100         Tel: 60-3-7651-7906         Germany - Heilbronn           Westborough, MA         China - Nanjing         Malaysia - Penang         Tel: 49-7131-72400           Tel: 774-760-0087         Tel: 80-528-5473-2460         Tel: 60-4-227-8870         Germany - Karlsruhe           Fax: 774-760-0088         China - Qingdao         Philippines - Manila         Tel: 49-721-625370           Chiago         Tel: 80-528-5027355         Tel: 63-268-0056         Germany - Karlsruhe           Tak: 630-285-0071         Tel: 80-21-3326-8000         Tel: 68-334-8870         Fax: 49-89-627-144-40           Fax: 630-285-0075         China - Shenpyang         Tai wan - Hain Chu         Germany - Karlsruhe           Fax: 630-285-0075         China - Shenpyang         Tai wan - Kaohsiung         Israel - Ra'anana           Tel: 9172-818-7423         Tel: 86-24-233-2820         Tel: 868-3-677-3366         Tel: 72-9744-7705           Tel: 9172-818-7423         Tel: 86-27-5980-5300         Tel: 86-2594-1351         Italy - Milan           Detroit         Tel: 86-27-5980-5300         Tel: 66-2694-1351         Italy - Padova           Tel: 248-848-4000         Tel: 86-27-5980-5302         Tel: 66-2694-1351         Italy - Padova           Tel: 248-94593         Tel: 80-29-8933-7522         Tel: 80-269-8933-752         Tel: 80-9	Tel: 512-257-3370	China - Hong Kong SAR	Malaysia - Kuala Lumpur	Tel: 49-2129-3766400
Westborough, MA         China - Nanjing         Malaysia - Penang         Tel: 49-7131-72400           Tel: 74-760-0087         Tel: 86-25-847.3-2460         Tel: 60-4227-8870         Germany - Karlsruhe           Fax: 774-760-0088         China - Oingdao         Philippines - Manila         Tel: 49-721-262570           Chicago         Tel: 86-532-802-7355         Tel: 63-232-634-9065         Germany - Munich           Tel: 630-285-0071         Tel: 65-6334-8870         Fax: 49-89-627-144-44           Tel: 630-285-0075         China - Shenyang         Talwan - Hsin Chu         Germany - Rosenheim           Dallas         Tel: 86-725-8864-2200         Tel: 86-7213-7830         Tel: 49-8031-534-5600           Addison, TX         China - Shenyang         Talwan - Hsin Chu         Germany - Rosenheim           Datlas         Tel: 86-755-8864-2200         Tel: 886-7213-7830         Tel: 49-8031-54560           Tel: 72-9744-7705         Talwan - Tajopiol         Haly - Milan         Tel: 49-8031-742611           Detroit         Tel: 86-755-8864-2200         Tel: 886-7213-7800         Tel: 49-9031-742611           Detroit         Tel: 86-756-8303-7252         Tel: 86-76-43151         Haly - Padova           Houston, TX         China - Xianen         Tel: 62-2641-7315         Heis 60-76-52586           Tel: 314-16-690340	Boston	Tel: 852-2943-5100	Tel: 60-3-7651-7906	Germany - Heilbronn
Tel:         774-780-0087         Tel:         86-25-8473-2460         Tel:         60-4227-8870         Germany - Karlsruhe           Fax:         774-760-0088         China - Qingdao         Philippines - Manila         Tel: 49-721-625370           Chicago         Tel:         65-32-8502-7355         Tel:         63-263-49005         Tel: 49-89-627-144-0           Tal:         Singapore         Tel: 49-89-627-144-0         Fax: 49-89-627-144-40           Tal:         Singapore         Tel: 49-89-627-144-40         Fax: 49-89-627-144-44           Sax:         Singapore         Tel: 49-89-627-144-40         Fax: 49-89-627-144-44           Sax:         Singapore         Tel: 49-89-627-144-40         Fax: 49-89-627-144-44           Dalas         Tel: 86-21-3326-8000         Tel: 86-331-8360         Tel: 49-8031-354-560           Addison, TX         China - Shenyang         Taiwan - Kaohslung         Israel - Ra' anana           Tel:         92-818-7423         Tel: 86-24-233-8200         Tel: 828-72-780-7630         Tel: 828-72-781-77300           Fax:         Tel: 86-26-82-31-1520         Tel: 86-26-82-43151         Haly - Milan           Datoin, TX         China - Xian         Vietnam - Ho Chi Minh         Tel: 30-331-42611           Tel: 242-49-49683         Tel: 86-29-833-7252 <t< td=""><td>Westborough, MA</td><td>China - Nanjing</td><td>Malaysia - Penang</td><td>Tel: 49-7131-72400</td></t<>	Westborough, MA	China - Nanjing	Malaysia - Penang	Tel: 49-7131-72400
Fax: 774-760-0088         China - Qingdao         Philippines - Manila         Tel: 49-721-625370           Chicago         Tel: 68-532-8502-7355         Tel: 632-823-9005         Germany - Munich           Itasca, IL         China - Shanghai         Singapore         Tel: 439-8627-144-04           Tel: 630-285-0071         Tel: 68-21-3326-8000         Tel: 65-6334-8870         Fax: 49-89-627-144-44           Fax: 630-285-0075         China - Shanghai         Taiwan - Hsin Chu         Germany - Rosenheim           Dallas         Tel: 68-21-737-8366         Tel: 49-80-633-4560         Tel: 49-80-633-45450           Addison, TX         China - Shenzhen         Taiwan - Hsin Chu         Germay - Rosenheim           Tel: 372-3744-7705         Taiwan - Suzhou         Tel: 686-57-73866         Tel: 49-803-534-560           Detroit         Tel: 86-755-8864-2200         Tel: 886-22508-8600         Tel: 39-0331-742611           Novi, MI         China - Wuhan         Thalland - Bangkok         Fax: 39-0331-466781           Tel: 248-48-4000         Tel: 86-756-33210         Tel: 88-629-803152         Tel: 39-049-7625286           Moston, TX         China - Xhana         Yeta         Ho Chi Minh         Tel: 39-049-7625286           Tel: 349-45833         Tel: 86-756-3210040         Tel: 42-74332         Tel: 40-747-50 <tr< td=""><td>Tel: 774-760-0087</td><td>Tel: 86-25-8473-2460</td><td>Tel: 60-4-227-8870</td><td>Germany - Karlsruhe</td></tr<>	Tel: 774-760-0087	Tel: 86-25-8473-2460	Tel: 60-4-227-8870	Germany - Karlsruhe
Chicago         Tel: 88-532-8502-7355         Tel: 83-2-634-9065         Germany - Munich           Itasca, IL         China - Shanghai         Singapore         Tel: 49-89-627-144-0           Fax: 630-285-0075         China - Shanghai         Taiwan - Hsin Chu         Germany - Rosenheim           Dallas         Tel: 86-32432-2829         Taiwan - Hsin Chu         Germany - Rosenheim           Dallas         China - Shenzhen         Taiwan - Kaohslung         Israel - Ra'anana           Tel: 972-818-7423         Tel: 86-755-8864-2200         Tel: 886-3-577-8360         Tel: 972-9-744-7705           Fax: 972-818-2924         China - Shenzhen         Taiwan - Kaohslung         Tel: 972-9-744-7705           Fax: 972-818-2924         China - Suzzhou         Tel: 886-72-13-7830         Tel: 972-9-744-7705           Detroit         Tel: 86-186-6233-1526         Tel: 866-250-8600         Tel: 90-9301-74/2611           Novi, MI         China - Xian         Vietnam + Oc hi Minh         Tel: 90-940-76252266           Tel: 281-894-5983         Tel: 86-29-8833-7522         Tel: 86-296-491-351         Tel: 949-496252266           Tel: 317-773-8323         China - Xhanen         Norway - Toncheim         Tel: 31-416-6800390           Tel: 317-773-8323         China - Shanzhen         Norway - Toncheim         Tel: 42-2-3325737	Fax: 774-760-0088	China - Qingdao	Philippines - Manila	Tel: 49-721-625370
Itasca, IL         China - Shanghai         Singapore         Tel: 49-80-627.144-40           Tel: 630-285-0071         Tel: 86-21-3326-8000         Tel: 66-6334-8870         Fax: 49-89-627.144-44           Dailas         Tel: 86-24-2334-2829         Teiwan - Hain Chu         Germany - Rosenheim           Dailas         Tel: 86-24-2334-2829         Teiwan - Kaohslung         Israel - Ra'nama           Dailas         Tel: 86-755-8864-2200         Tel: 886-3-577-8366         Tel: 972-9744-7705           Tel: 972-9744-7705         Taiwan - Taipei         Italy - Milan           Detroit         Tel: 86-755-8864-2200         Tel: 886-2-2508-8600         Tel: 39-0331-742611           Novi, MI         China - Shanghai         Taiwan - Taipei         Italy - Milan           Detroit         Tel: 86-756-88600         Tel: 39-0331-742611         Tel: 972-9744-7705           Tel: 248-848-4000         Tel: 86-756-8805300         Tel: 686-294-1351         Italy - Padova           Houston, TX         China - Xian         Vietnam - Ho Chi Minh         Tel: 39-049-7625286           Tel: 84-84-8000         Tel: 86-768-3210040         Tel: 84-28-5448-2100         Meterlands - Drunen           Tel: 317-73-8233         China - Zhuhal         Saatagaa         Saatagaa         Saatagaa           Tel: 317-736-62380         Los	Chicago	Tel: 86-532-8502-7355	Tel: 63-2-634-9065	Germany - Munich
Tel: 630-285-0071         Tel: 86-21-3326-8000         Tel: 65-6334-8870         Fax: 49-89-627.144-44           Fax: 630-285-0075         China - Shenyang         Taiwan - Hsin Chu         Germany - Rosenheim           Dallas         Tel: 86-24-2334-2829         Tel: 886-357-8366         Tel: 49-8031-354-560           Addison, TX         China - Shenzhen         Taiwan - Kaohslung         Israel - Ra'anana           Tel: 98-72-818-7423         Tel: 86-756-8864-2200         Tel: 886-7213-7830         Tel: 872-9-744-7705           Fax: 972-818-7423         Tel: 86-756-8864-2200         Tel: 886-7-213-7830         Tel: 872-9-744-7705           Fax: 90-031-742611         Tel: 86-186-623-31-526         Tel: 86-26-22608-8600         Tel: 39-0331-742611           Novi, MI         China - Stan         Thailand - Bangkok         Fax: 39-0331-742611           Houston, TX         China - Xian         Vietnan - Ho Chi Minh         Tel: 30-049-7625266           Tel: 281-884-4000         Tel: 86-29-8833-7252         Tel: 66-29-484-2100         Netherlands - Drunen           Indianapolis         China - Zhuhai         Tel: 84-28-5448-2100         Netherlands - Drunen           Tel: 281-894-692-8633         Tel: 86-576-3210040         Tel: 48-22-3325737           Kission Viejo, CA         Tel: 48-756-3210040         Tel: 48-22-3325737	Itasca. IL	China - Shanghai	Singapore	Tel: 49-89-627-144-0
Fax: 630-285-0075         China - Shenyang         Tai: wan - Hsin Chu         Germany - Rosenheim           Dalas         Tei: 86-24-2334-2829         Tei: 886-577-3806         Tei: 49-8031-354-560           Addison, TX         China - Shenzhen         Taiwan - Kaohsiung         Israel - Ra'anana           Tei: 972-818-7423         Tei: 86-755-8864-2200         Tei: 886-7-213-7830         Tei: 92-9-744-7705           Fax: 972-818-2924         China - Suzhou         Taiwan - Taipei         Italy - Nilan           Detroit         Tei: 86-186-6233-1526         Tei: 886-72-13-7830         Tei: 89-0331-742611           Novi, MI         China - Wuhan         Taiwan - Taipei         Italy - Nilan           Tei: 248-848-4000         Tei: 86-29-683-7520         Tei: 86-29-683-752         Italy - Padova           Houston, TX         China - Xian         Vietnam - Ho Chi Minh         Tei: 39-049-7625286           Tei: 248-848-4000         Tei: 86-29-683-7522         Tei: 84-28-5448-2100         Netherlands - Drunen           Indianapolis         China - Xianen         Tei: 84-28-5448-2100         Netwards - Surgen           Ici: 317-773-5453         Tei: 86-59-2383138         Tei: 86-29-6831-104         Norway - Tondheim           Tei: 317-773-5453         Tei: 86-756-3210040         Tei: 48-24-23232737           Tei: 917-73-5453 </td <td>Tel: 630-285-0071</td> <td>Tel: 86-21-3326-8000</td> <td>Tel: 65-6334-8870</td> <td>Fax: 49-89-627-144-44</td>	Tel: 630-285-0071	Tel: 86-21-3326-8000	Tel: 65-6334-8870	Fax: 49-89-627-144-44
Dalas         Tel: 86-24-233-2829         Tel: 88-3-577-8366         Tel: 49-8031-354-560           Addison, TX         China - Shenzhen         Taiwan - Kaobisung         Israel - Ra'anana           Tel: 972-818-7423         Tel: 86-755-8864-2200         Tel: 886-7-213-7830         Tel: 972-9744-7705           Taiwan - Taipei         Taiwan - Taipei         Tel: 972-9744-7705         Taiwan - Taipei         Tel: 972-9744-7705           Tel: 818-18-2924         China - Suzbou         Tel: 886-2-2508-8600         Tel: 39-0331-742611         Tel: 90-0331-742611           Novi, MI         China - Xiann         Tel: 68-2-5980-5300         Tel: 66-2-694-1351         Tel: 39-049-7625286           Tel: 281-894-5983         Tel: 86-29-89833-7252         Tel: 84-28-5448-2100         Netherlands - Drunen           Indianapolis         China - Xiame         Vietumar Ho Chi Minh         Tel: 31-416-690399           Tel: 317-773-8323         China - Zhuhai         Fax: 31-416-690340         Fax: 31-416-690340           Tel: 317-773-8453         Tel: 86-756-3210040         Fai: 47-7284388         Poland - Warsaw           Tel: 391-94-662-9623         Tel: 40-21-407-87-50         Fax: 34-416-690340           Tel: 99-462-9623         Fai: 49-1708-08-90         Fai: 34-91-708-08-90           Fai: 99-14-7704         Fai: 40-710-70-70         Fai: 40-91-708	Fax: 630-285-0075	China - Shenvang	Taiwan - Hsin Chu	Germany - Rosenheim
Addison, TX         China - Shenzhen         Taiwan - Kaohsiung         Israel - Ra'anana           Tei: 972-818-7423         Tei: 86-755-8864-2200         Tei: 886-7-213-7830         Tei: 97-29-744-7705           Fax: 972-818-2924         China - Suzhou         Taiwan - Taipei         Italy - Milan           Detroit         Tei: 86-186-6233-1526         Tei: 886-22508-8600         Tei: 90-031-742611           Novi, MI         China - Wuhan         Thailand - Bangkok         Fax: 39-031-4466781           Tei: 284-848-4000         Tei: 86-2-9508-5300         Tei: 66-2-694-1351         Italy - Padova           Houston, TX         China - Xian         Vietnam - Ho Chi Minh         Tei: 39-031-466781           Tei: 281-894-5983         Tei: 66-29-833-7522         Tei: 84-28-5448-2100         Metherlands - Drunen           Indianapolis         China - Xianen         Tei: 84-28-5448-2100         Norway - Trondheim           Tei: 317-773-5453         Tei: 66-59-2380138         Fax: 314-16-690399         Fax: 314-16-690340           Tei: 317-773-5453         Tei: 86-76-63210040         Norway - Trondheim         Tei: 47-2284388           Tei: 317-536-2380         Tei: 86-76-63210040         Tei: 49-21-407-87-50         Spain - Madrid           Tei: 91-93-1773-7800         Tei: 86-76-752         Spain - Madrid         Tei: 49-21-407-87-50	Dallas	Tel: 86-24-2334-2829	Tel: 886-3-577-8366	Tel: 49-8031-354-560
Tel: 972-818-7423       Tel: 86-755-8864-2200       Tel: 866-7-213-7830       Tel: 972-9-744-7705         Fax: 972-818-2924       China - Suzhou       Taiwan - Taipei       Italy - Milan         Detroit       Tel: 86-6233-1526       Tel: 886-22508-8600       Tel: 30-0331-742611         Novi, MI       China - Wuhan       Tailalad - Bangkok       Fax: 39-0331-466781         Tel: 248-848-4000       Tel: 86-27-5980-5300       Tel: 66-2-694-1351       Italy - Padova         Houston, TX       China - Xian       Vietnam - Ho Chi Minh       Tel: 39-049-7625286         Tel: 248-848-4000       Tel: 86-27-5980-5300       Tel: 84-28-5448-2100       Netherlands - Drunen         Indianapolis       China - Xianen       Tel: 84-28-5448-2100       Netherlands - Drunen         Noblesville, IN       Tel: 86-592-2388138       Fax: 317-173-8323       Tel: 86-766-3210040         Tel: 317-773-8323       China - Zhuhai       Norway - Trondheim         Fax: 317-773-6423       Tel: 86-766-3210040       Tel: 47-2884388         Poland - Warsaw       Tel: 40-28-750       Spain - Madrid         Tel: 949-462-9608       Tel: 40-21-407-87-50       Spain - Madrid         Tel: 949-462-9608       Tel: 40-21-407-87-50       Spain - Madrid         Tel: 949-462-9608       Tel: 40-31-704-60-40       Sweden - 60thenberg	Addison. TX	China - Shenzhen	Taiwan - Kaohsiung	Israel - Ra'anana
Fax: 972-818-2924         China - Suzhou         Taiwan - Taipei         Italy - Milan           Detroit         Tel: 86-186-6233-1526         Tel: 88-2-2508-8600         Tel: 39-0331-742611           Novi, MI         China - Wuhan         Thailand - Bangkok         Fax: 39-0331-466781           Tel: 284-848-4000         Tel: 86-27-5980-5300         Tel: 66-2-694-1351         Italy - Padova           Houston, TX         China - Xian         Vietnam - Ho Chi Minh         Tel: 39-049-7625286           Tel: 281-894-5983         Tel: 86-29-8833-7252         Tel: 84-28-5448-2100         Netherlands - Drunen           Indianapolis         China - Xiamen         Tel: 86-592-238138         Fax: 31-416-690340           Tel: 317-773-5453         Tel: 86-756-3210040         Tel: 47-7284388         Poland - Warsaw           Tel: 317-536-2380         Tel: 86-756-3210040         Tel: 42-27-3285737         Romain - Bucharest           Tel: 949-462-9523         Tel: 84-27-325737         Romain - Bucharest         Tel: 40-21-407-87-50           Fax: 949-462-9608         Tel: 91-944-7510         Spain - Madrid         Tel: 42-92-7080-90           Raleigh, NC         Tel: 49-7708-08-91         Sweden - Gothenberg         Tel: 46-810704-60-40           Sweden - Gothenberg         Tel: 408-735-9110         Sweden - Gothenberg         Tel: 46-81090-4664	Tel: 972-818-7423	Tel: 86-755-8864-2200	Tel: 886-7-213-7830	Tel: 972-9-744-7705
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