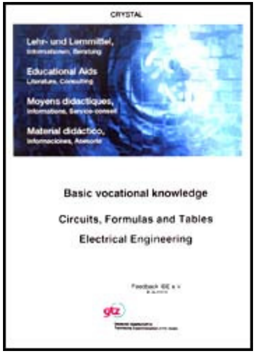

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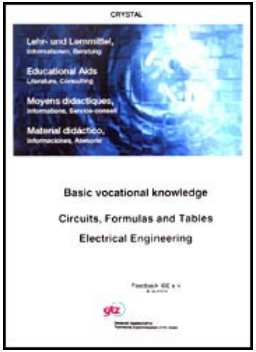

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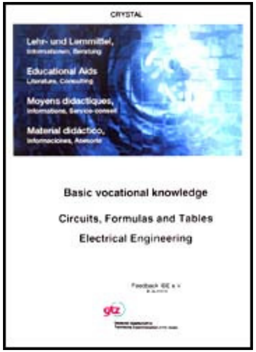
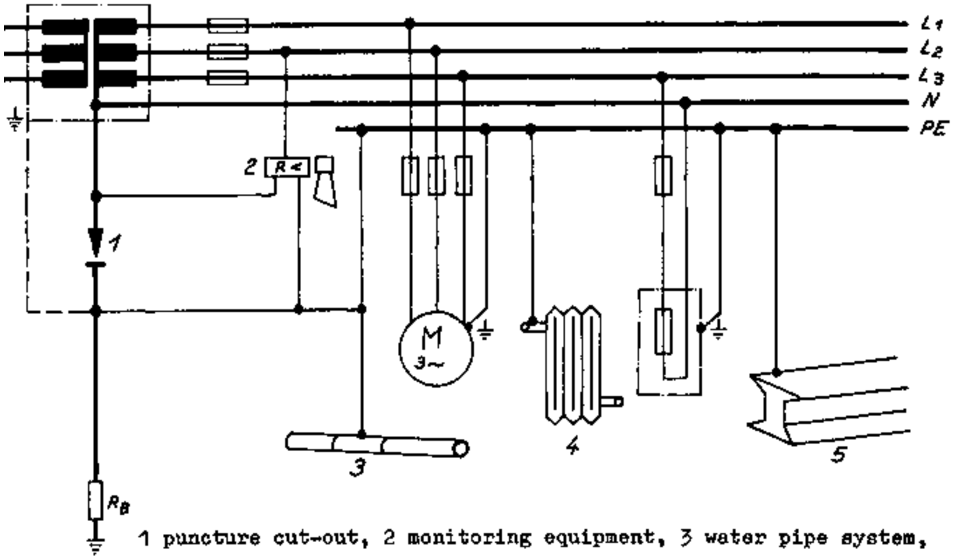
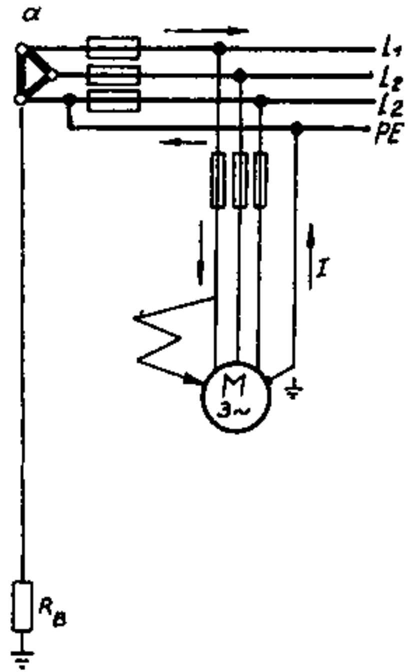


8. Protective Circuits

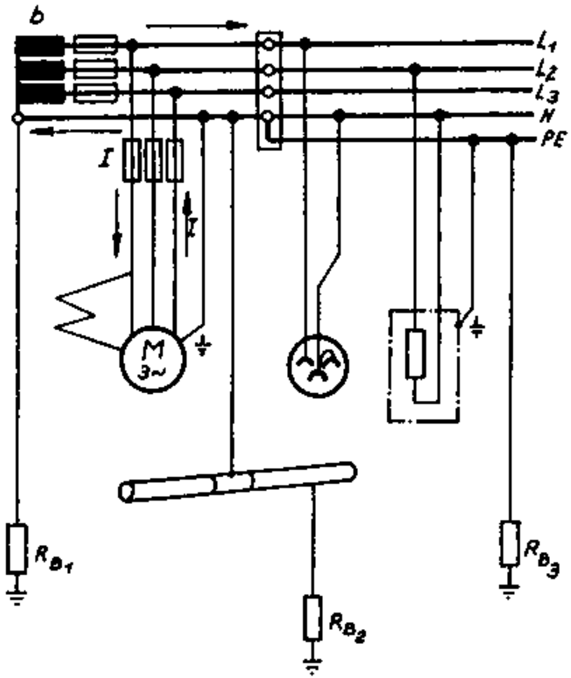


1 puncture cut-out, 2 monitoring equipment, 3 water pipe system, 4 heating system, 5 metal structure

Protective wire in a three-phase current system

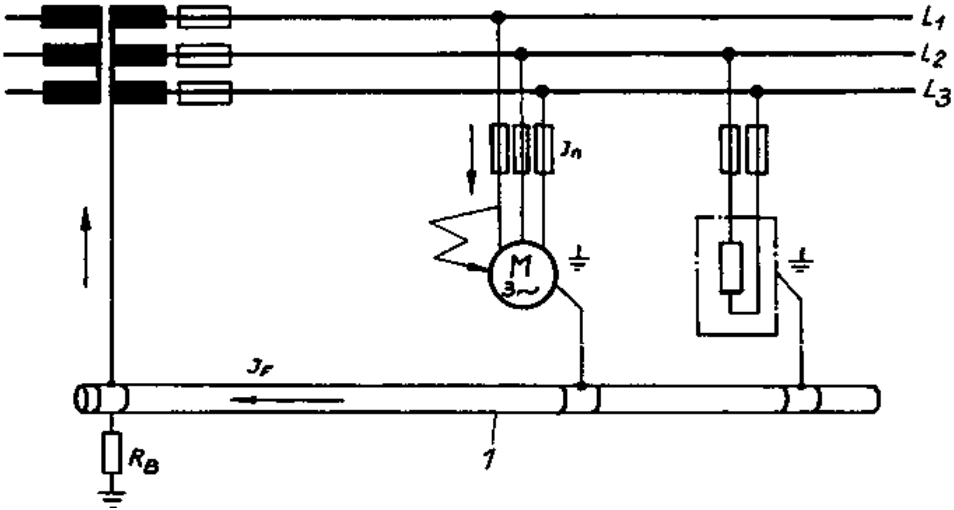


Earthing (Three-phase a-c three wire system)

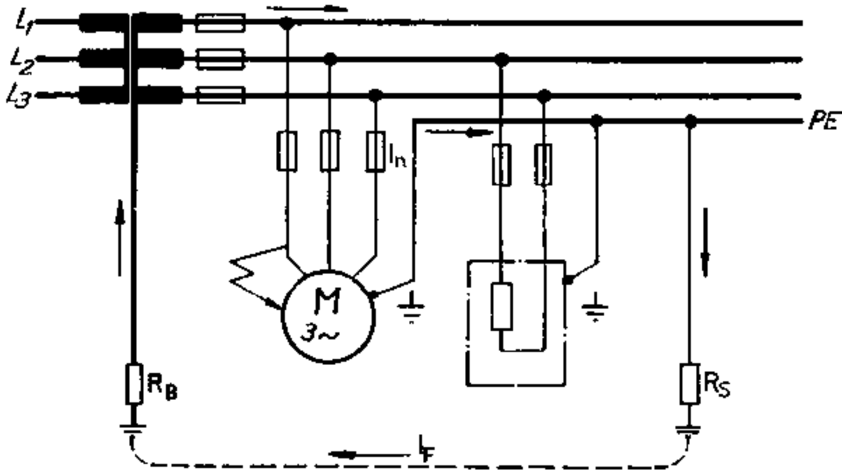


Earthing (Three-phase a-c four wire system)

<u>Protective Earthing</u>

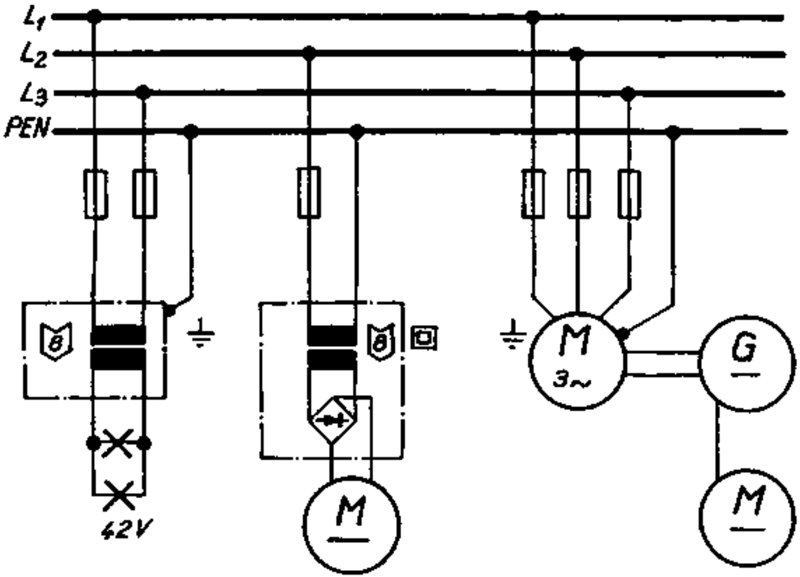


Reflux of the leakage current via water pipe system (1)



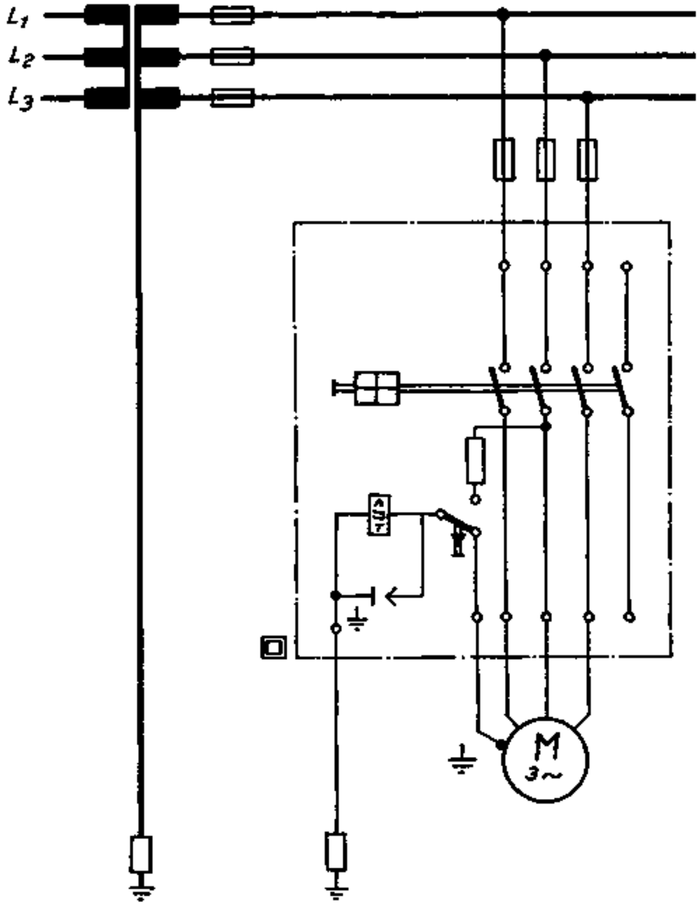
Reflux of the leakage current via earth

I_F leakage current, I_n rated current of the fusible cut-out



Circuit for Generating Protective Low Voltage

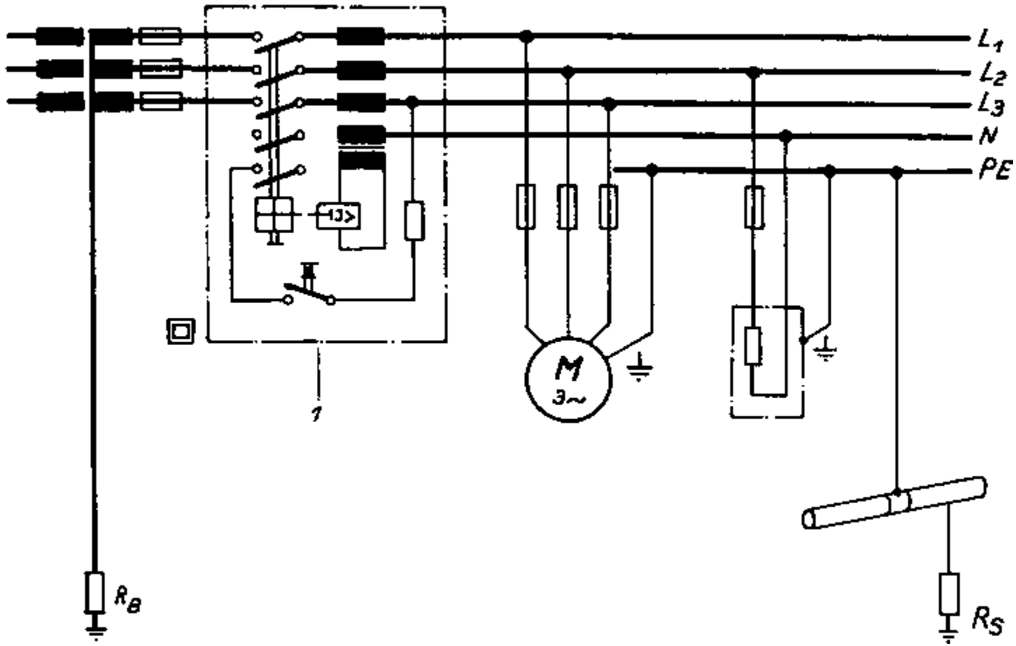
Fault-voltage Protective Circuit



in a three-phase three-wire system

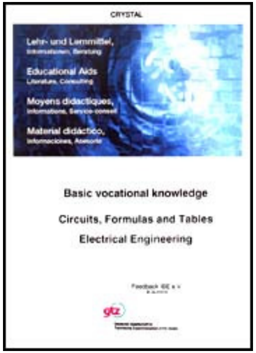
1 fault-voltage circuit breaker

Fault-current Protective Circuit



in a three-phase four-wire system

1 fault-current circuit breaker



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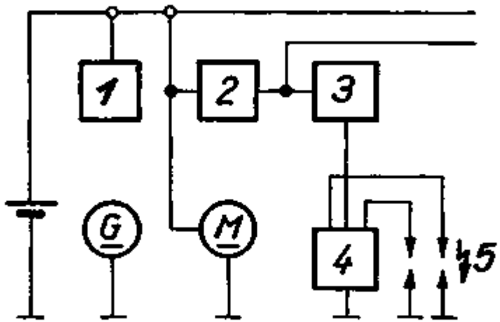
9. Circuits in Motor Vehicles

Block diagram

The block diagram represents the simplified circuit. Only the essential parts are taken into consideration. The devices are copied by means of rectangles or squares and properly marked.

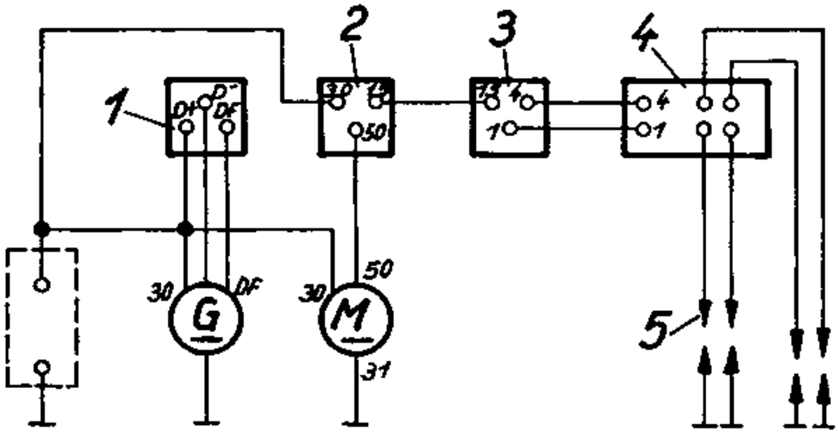


1 regulator, 2 ignition switch, 3 ignition coil, 4 ignition distributor, 5 sparking plugs

Figure

Terminal diagram

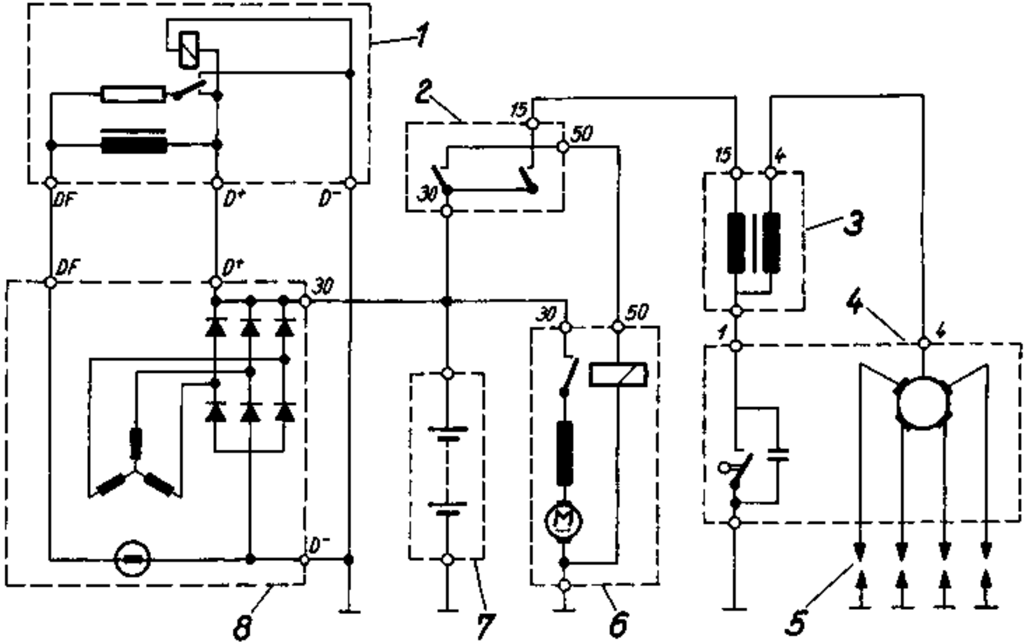
The terminal diagram represents the electrical connection between the devices. Thus it allows the exchange of products, devices and parts of devices. The components are represented with the corresponding lines, junctions and terminal designations.



Figure

Circuit diagram

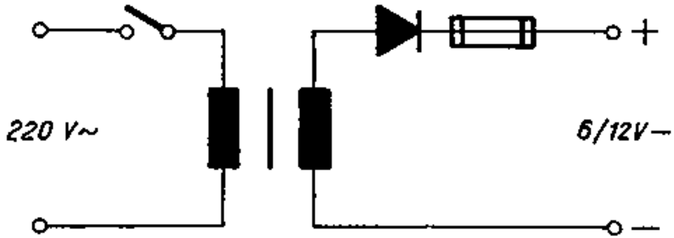
The circuit diagram is the detailed representation of a circuit. It represent the operating method of an electrical system or of single devices. The devices are drawn in their basic setting and in dead condition.



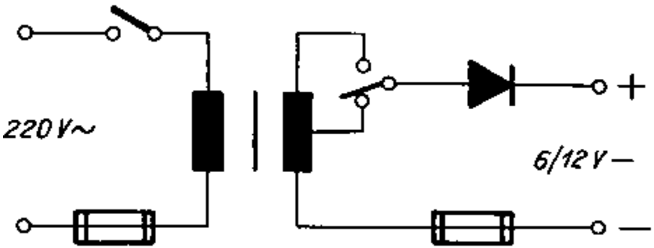
1 regulator,
2 ignition switch,
3 ignition coil,
4 ignition distributor,
5 sparking plugs,
6 starter,
7 accumulator,
8 alternator

Figure

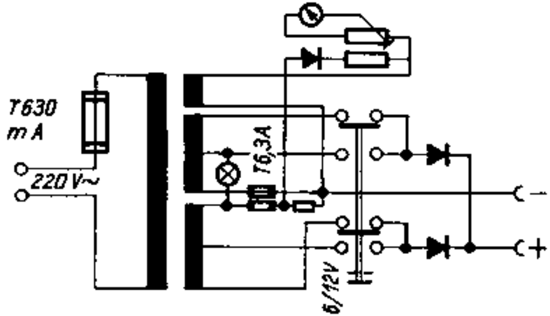
9.1. Battery Charge



General wiring-diagram



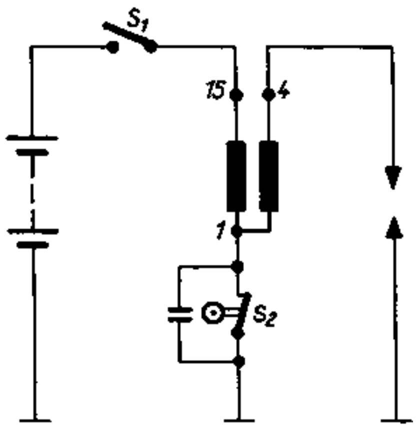
Battery charger 6/12 V switchable



Battery charger 6/12 switchable with built-in charge indicator lamp and measuring instrument

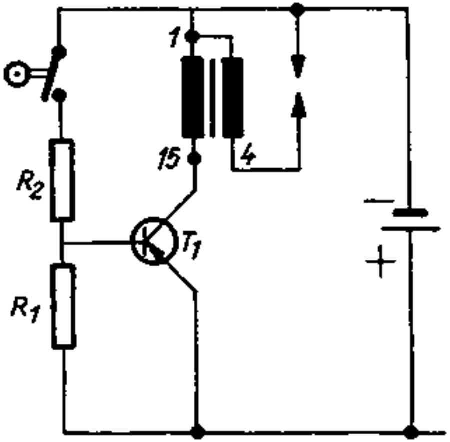
9.2. Ignition Systems

Battery-ignition systems

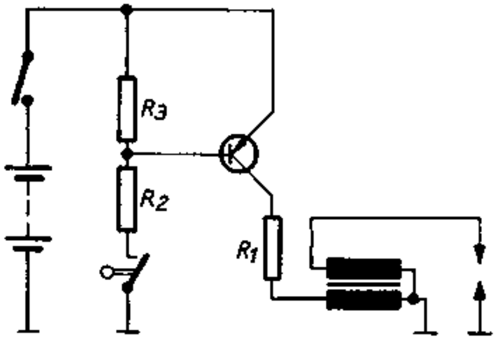


General wiring diagram

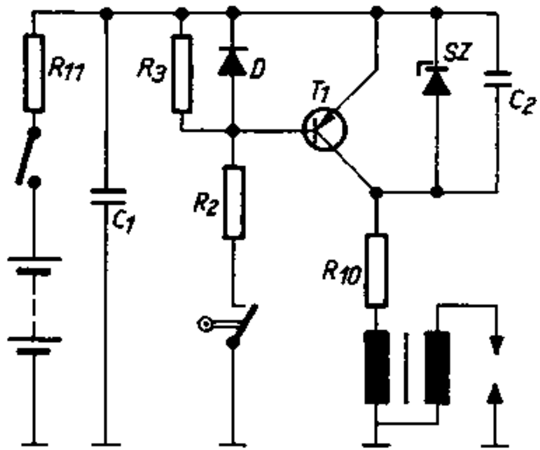
Transistorized ignition systems



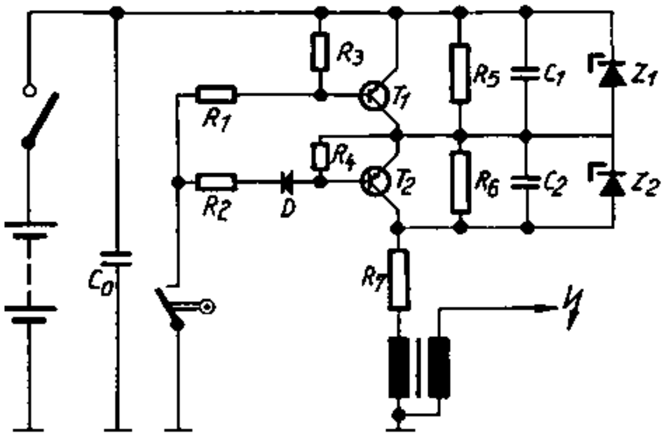
General wiring diagram



Variants of transistorized ignition systems (A)

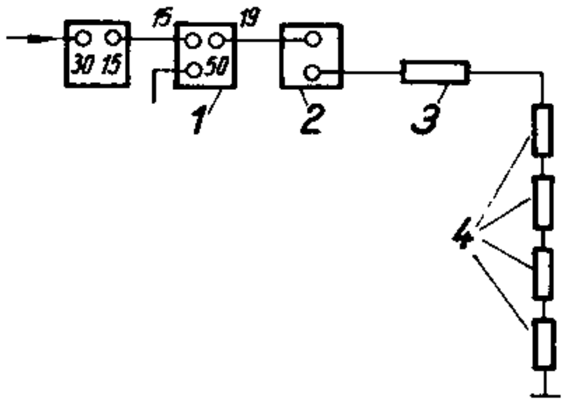


Variants of transistorized ignition systems (B)



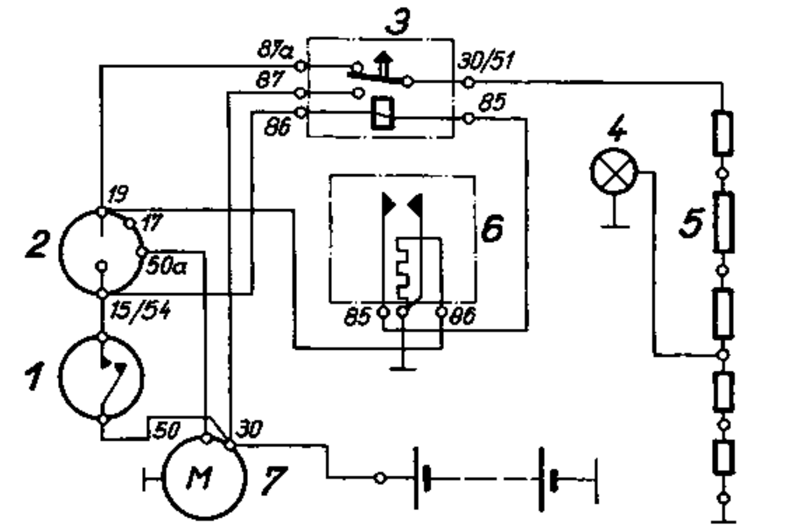
Transistorized ignition (Bosch)

9.3. Starting Aid for Diesel Engines



Terminal diagram of a preheating system

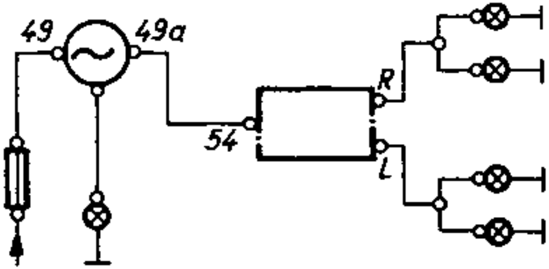
1 glow-plug and starter switch, 2 glow-plug indicator, 3 ballast resistor, 4 glow plugs



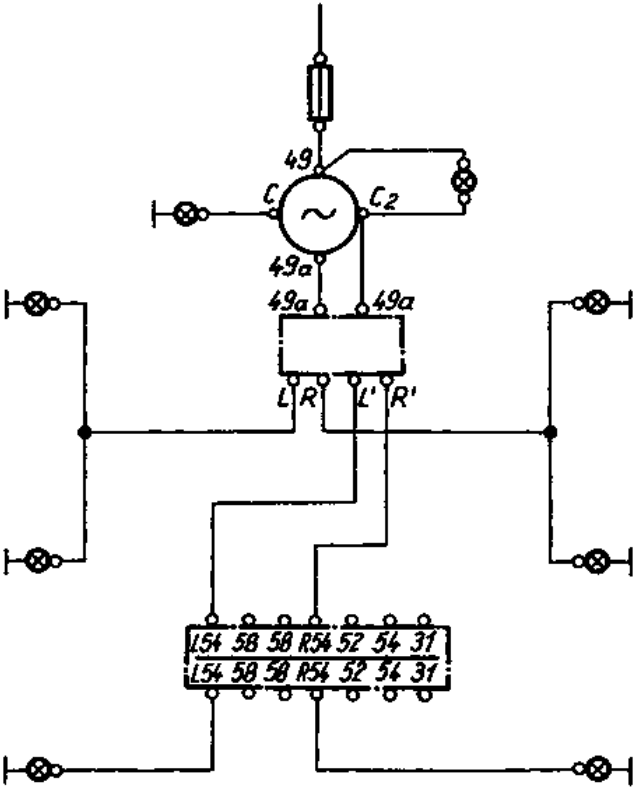
Preheating with automatic re-annealing after starting

1 headlamp-ignition switch, 2 glow-plug and starter switch, 3 contactor, 4 charge indicator lamp (as glow-plug indicator), 5 resistor, 6 time-delay switch, 7 starter

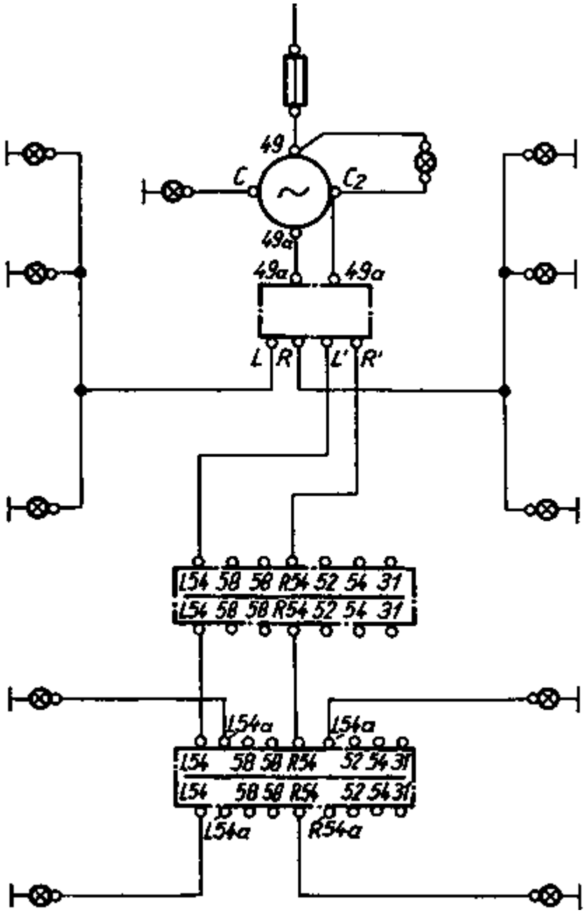
9.4. Turn-signal Flasher



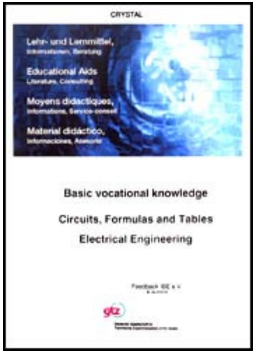
Turn-signal flasher with two turn-signal lamps and indicator lamp



Turn-signal flasher with three turn-signal lamps and turn-signal lamp



Turn-signal flasher with three turn-signal lamps and two turn-signal lamps



10. Tables

Table 1 Natural values of the trigonometric functions sine and cosine

sin 0°...sin 15°

minute	0	6	12	18	24	30	36	42	48	54	60	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
0	0,00000	00175	00349	00524	00698	00873	01047	01222	01396	01571	01745	89
1	01745	01920	02094	02269	02443	02618	02792	02967	03141	03316	03490	88
2	03490	03664	03839	04013	04188	04362	04536	04711	04885	05059	05234	87
3	05234	05408	05582	05756	05931	06105	06279	06453	06627	06802	06976	86
4	06976	07150	07324	07498	07672	07846	08020	08194	08368	08542	08716	85
5	08716	08889	09063	09237	09411	09585	09758	09932	10106	10279	10453	84
6	10453	10626	10800	10973	11147	11320	11494	11667	11840	12014	12187	83
7	12187	12360	12533	12706	12880	13053	13226	13399	13572	13744	13917	82
8	13917	14090	14263	14436	14608	14781	14954	15126	15299	15471	15643	81
9	15643	15816	15988	16160	16333	16505	16677	16849	17021	17193	17365	80
10	0,17365	17537	17708	17880	18052	18224	18395	18567	18738	18910	19081	79
11	19081	19252	19423	19595	19766	19937	20108	20279	20450	20620	20791	78
12	20791	20962	21132	21303	21474	21644	21814	21985	22155	22325	22495	77
13	22495	22665	22835	23005	23175	23345	23514	23684	23853	24023	24192	76
14	24192	24362	24531	24700	24869	25038	25207	25376	25545	25713	25882	75
	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**
	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
												cos 75°...cos 90°

Natural values of the trigonometric functions sine and cosine

sin 15°...30°											
minute	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
15	25882	26050	26219	26387	26556	26724	26892	27060	27228	27396	27564	74
16	27564	27731	27899	28067	28234	28402	28569	28736	28903	29070	29237	73
17	29237	29404	29571	29737	29904	30071	30237	30403	30570	30736	30902	72
18	30902	31068	31233	31399	31565	31730	31896	32061	32227	32392	32557	71
19	32557	32722	32887	33051	33216	33381	33545	33710	33874	34038	34202	70
20	0,34202	34366	34530	34694	34857	35021	35184	35347	35511	35674	35837	69
21	35837	36000	36162	36325	36488	36650	36812	36975	37137	37299	37461	68
22	37461	37622	37784	37946	38107	38268	38430	38591	38752	38912	39073	67
23	39073	39234	39394	39555	39715	39875	40035	40195	40355	40514	40674	66
24	40674	40833	40992	41151	41310	41469	41628	41787	41945	42104	42262	65
25	42262	42420	42578	42736	42894	43051	43209	43366	43523	43680	43837	64
26	43837	43994	44151	44307	44464	44620	44776	44932	45088	45243	45399	63
27	45399	45554	45710	45865	46020	46175	46330	46484	46639	46793	46947	62
28	46947	47101	47255	47409	47562	47716	47860	48022	48175	48328	48481	61
29	48481	48634	48786	48938	49090	49242	49394	49546	49697	49849	50000	60
	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**
	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
											cos 75°...60°

Natural values of the trigonometric functions sine and cosine

sin 30°...45°											
minute	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
30	0,50000	50151	50303	50453	50603	50754	50904	51054	51204	51354	51504	59
31	51504	51653	51803	51952	52101	52250	52399	52547	52696	52844	52992	58
32	52992	53140	53288	53435	53583	53730	53877	54024	54171	54317	54464	57
33	54464	54610	54756	54902	55048	55194	55339	55484	55630	55775	55919	56
34	55919	56064	56208	56353	56497	56641	56784	56928	57071	57215	57358	55
35	57358	57501	57643	57786	57928	58070	58212	58354	58496	58637	58779	54
36	58779	58920	59061	59201	59342	59482	59622	59763	59902	60042	60182	53
37	60182	60321	60460	60599	60738	60876	61015	61153	61291	61429	61566	52
38	61566	61704	61841	61978	62115	62251	62388	62524	62660	62796	62932	51
39	62932	63068	63203	63338	63473	63608	63742	63877	64011	64145	64279	50
40	0,64279	64412	64546	64679	64812	64945	65077	65210	65342	65474	65606	49
41	65606	65738	65869	66000	66131	66262	66393	66523	66653	66783	66913	48
42	66913	67043	67172	67301	67430	67559	67688	67816	67944	68072	68200	47
43	68200	68327	68455	68582	68709	68835	68962	69088	69214	69340	69466	46
44	69466	69591	69717	69842	69966	70091	70215	70339	70463	70587	70711	45
	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**
	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
											cos 60°...45°

Natural values of the trigonometric functions sine and cosine

sin 45°...60°												
minute	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
45	0,70711	70834	70957	71080	71203	71325	71447	71569	71691	71813	71934	44
46	71934	72055	72176	72297	72417	72537	72657	72777	72897	73016	73135	43
47	73135	73254	73373	73491	73610	73728	73846	73963	74080	74198	74314	42
48	74314	74431	74548	74664	74780	74896	75011	75126	75241	75356	75471	41
49	75471	75585	75700	75813	75927	76041	76154	76267	76380	76492	76604	40
50	0,76604	76717	76828	76940	77051	77162	77273	77384	77494	77605	77715	39
51	77715	77824	77934	78043	78152	78261	78369	78478	78586	78694	78801	38
52	78801	78908	79016	79122	79229	79335	79441	79547	79653	79758	79864	37
53	79864	79968	80073	80178	80282	80386	80489	80593	80696	80799	80902	36
54	80902	81004	81106	81208	81310	81412	81513	81614	81714	81815	81915	35
55	81915	82015	82115	82214	82314	82413	82511	82610	82708	82806	82904	34
56	82904	83001	83098	83195	83292	83389	83485	83581	83676	83772	83867	33
57	83867	83962	84057	84151	84245	84339	84433	84526	84619	84712	84805	32
58	84805	84897	84989	85081	85173	85264	85355	85446	85536	85627	85717	31
59	85717	85806	85896	85985	86074	86163	86251	86340	86427	86515	86603	30
	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**

	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
cos 30°...45°												

Natural values of the trigonometric functions sine and cosine sin

sin 60°...75°												
minute	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
60	0,86603	86690	86777	86863	86949	87036	87121	87207	87292	87377	87462	29
61	87462	87546	87631	87715	87798	87882	87965	88048	88130	88213	88295	28
62	88295	88377	88458	88539	88620	88701	88782	88862	88942	89021	89101	27
63	89101	89180	89259	89337	89415	89493	89571	89649	89726	89803	89879	26
64	89879	89956	90032	90108	90183	90250	90334	90408	90483	90557	90631	25
65	90631	90704	90778	90851	90924	90996	91068	91140	91212	91283	91355	24
66	91355	91425	91496	91566	91636	91706	91775	91845	91914	91982	92050	23
67	92050	92119	92186	92254	92321	92388	92455	92521	92587	92653	92718	22
68	92718	92784	92849	92913	92978	93042	93106	93169	93232	93295	93358	21
69	93358	93420	93483	93544	93606	93667	93728	93789	93849	93909	93969	20
70	0,93969	94029	94088	94147	94206	94264	94322	94380	94438	94495	94552	19
71	94552	94609	94665	94721	94777	94832	94888	94943	94997	95052	95106	18
72	95106	95159	95213	95266	95319	95372	95424	95476	95528	95579	95630	17
73	95630	95681	95732	95782	95832	95882	95931	95981	96029	96078	96126	16
74	96126	96174	96222	96269	96316	96363	96410	96456	96502	96547	96593	15

	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**
	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
											cos 15°...30°

Natural values of the trigonometric functions sine and cosine

sin 75°...90°											
minute	**0**	**6**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	
degree	**,0**	**,1**	**,2**	**,3**	**,4**	**,5**	**,6**	**,7**	**,8**	**,9**	**(1,0)**	
75	96593	96638	96682	96727	96771	96815	96858	96902	96945	96987	97030	14
76	97030	97072	97113	97155	97196	97237	97278	97318	97358	97398	97437	13
77	97437	97476	97515	97553	97592	97630	97667	97705	97742	97778	97815	12
78	97815	97851	97887	97922	97958	97992	98027	98061	98096	98129	98163	11
79	98163	98196	98229	98261	98294	98325	98357	98389	98420	98450	98481	10
80	0,98481	98511	98541	98570	98600	98629	98657	98686	98714	98741	98769	9
81	98769	98796	98823	98849	98876	98902	98927	98953	98978	99002	99027	8
82	99027	99051	99075	99098	99122	99144	99167	99189	99211	99233	99255	7
83	99255	99276	99297	99317	99337	99357	99377	99396	99415	99434	99452	6
84	99452	99470	99488	99506	99523	99540	99556	99572	99588	99604	99619	5
85	99619	99635	99649	99664	99678	99692	99705	99731	99731	99744	99756	4
86	99756	99768	99780	99792	99803	99813	99824	99834	99844	99854	99863	3
87	99863	99872	99881	99889	99897	99905	99912	99919	99926	99933	99939	2
88	99939	99945	99951	99956	99961	99966	99979	99974	99978	99982	99985	1

89	99985	99988	99990	99993	99995	99996	99998	99999	99999	1.00000	1.00000	0
	(1,0)	**,9**	**,8**	**,7**	**,6**	**,5**	**,4**	**,3**	**,2**	**,1**	**,0**	**degree**
	60	**54**	**48**	**42**	**36**	**30**	**24**	**18**	**12**	**6**	**0**	**minute**
cos 15°...0°												

Table 2 Resistances and weights of copper wires

Diameter	Cross section	Resistance per km with 15°(288 k)	Length of a wire of 1 Ω	Weight per km	Length of a wire of 1 kg
mm	mm^2	Ω	m	kg	m
0,1	0,0079	2215	0,4514	0,070	14306
0,2	0,0314	553,9	1,856	0,280	3577
0,3	0,0707	246,2	4,062	0,629	1590
0,4	0,1257	138,5	7,222	1,118	894,1
0,5	0,1964	88,62	11,28	1,748	572,2
0,6	0,2827	61,54	16,25	2,516	397,4
0,7	0,3848	45,21	22,12	3,425	292,0
0,8	0,5026	34,62	28,89	4,474	223,5
0,9	0,6362	27,35	36,56	5,662	176,6
1,0	0,7854	22,15	45,14	6,990	143,1
1,1	0,9503	18,31	54,62	8,458	118,2
1,2	1,1310	15,38	65,00	10,07	99,35

1,3	1,3273	13,11	76,28	11,81	84,65
1,4	1,5394	11,30	88,47	13,70	72,99
1,5	1,7671	9,846	101,6	15,73	63,58
1,6	2,0106	8,654	115,6	17,89	55,88
1,7	2,2698	7,666	130,5	20,20	49,50
1,8	2,5447	6,838	146,2	22,65	44,15
1,9	2,8353	6,137	162,9	25,23	39,63
2,0	3,1416	5,539	180,6	27,96	35,77
2,1	3,4636	5,024	199,1	30,83	32,44
2,2	3,8013	4,577	218,5	33,83	29,56
2,3	4,1548	4,188	238,8	36,98	27,04
2,4	4,5239	3,846	260,0	40,26	24,84
2,5	4,9087	3,545	282,1	43,69	22,89
2,6	5,3093	3,277	305,1	47,25	21,16
2,7	5,7256	3,039	329,1	50,96	19,62
2,8	6,1575	2,826	353,9	54,80	18,25
2,9	6,6052	2,634	379,6	58,79	17,01
3,0	7,0686	2,462	406,2	62,91	15,90
3,1	7,5477	2,305	433,8	67,17	14,89
3,2	8,0425	2,164	462,2	71,58	13 79
3,3	8,5530	2,034	491,6	76,12	13,14
3,4	9,0792	1,916	521,8	80,80	12,38

3,5	9,6211	1,809	552,9	85,63	11,68
3,6	10,1790	1,709	585,0	90,59	11,04
3,7	10,752	1,618	617,9	95,69	10,45
3,8	11,341	1,534	651,8	100,9	9,907
3,9	11,946	1,457	686,5	106,3	9,406
4,0	12,566	1,385	722,2	111,8	8,941
4,1	13,203	1,318	758,8	117,5	8,510
4,2	13,854	1,256	796,2	123,3	8,110
4,3	14,522	1,198	834,6	129,2	7,737
4,4	15,205	1,144	873,9	135,3	7,389
4,5	15,904	1,094	914,0	141,5	7,065
4,6	16,619	1,047	955,1	147,9	6,761
4,7	17,349	1,003	997,1	154,4	6,476
4,8	18,096	0,9616	1040	161,1	6,209
4,9	18,857	0,9227	1084	167,8	5,958
5,0	19,635	0,8862	1128	174,7	5,722
5,1	20,428	0,8518	1174	181,8	5,500
5,2	21,237	0,8193	1221	189,0	5,291
5,3	22,062	0,7887	1268	196,4	5,093
5,4	22,902	0,7598	1316	203,8	4,906
5,5	23,758	0,7324	1365	211,5	4,729
5,6	24,630	0,7065	1416	219,2	4,562
5,7	25,518	0,6819	1467	227,1	4,403

5,8	26,421	0,6586	1518	235,1	4,253
5,9	27,340	0,6463	1571	243,3	4,110
6,0	28,274	0,6154	1625	251,6	3,974
6,1	29,225	0,5974	1680	260,1	3,845
6,2	30,191	0,5763	1735	268,7	3,722
6,3	31,172	0,5582	1792	277,4	3,604
6,4	32,170	0,5409	1849	286,3	3,493
6,5	33,183	0,5244	1907	295,3	3,386
6,6	34,212	0,5086	1966	304,5	3,284
6,7	35,257	0,4935	2026	313,8	3,187
6,8	36,317	0,4791	2087	323,2	3,094
6,9	37,393	0,4653	2149	332,8	3,005

Table 3 Specific resistance and conductivity of essential materials at 20° C (193 K)

Material	Spec. Resistance	Conductivity
	$\frac{\Omega\, mm^2}{m}$	$\frac{m}{\Omega\, mm^2}$
Aluminium, soft	0,028	36
Lead	0,2	5
Gold	0,022	45
Copper E-Cu, soft	0,01754	57
Brass Ms 58	0,059	17

Brass Ms 63	0,071	14
Nickel silver NiMs	0,5...0,15	2,0...6,7
Platinum	0,098	10,2
Mercury	0,960	1,042
Silver	0,01629	61,4
Steel, ingot iron	0,12	8
Grey iron	1	1
Tungsten	0,059	17
Zinc	0,062	16
	Resistance alloy:	
Chrome nickel	1...1,2	1...0,83
Constantan (WM 50)	0,5	2
Manganin	0,4	2,5
Niccolite	0,5	2
Al-Cr-Steel	1,4	0,7
Arc lamp carbon	13...100	0,08...0,01

Table 4 Temperature coefficient

Material	Temperature coefficient of an electrical resistance between 0° and 100° C (173 and 273 K)
Aluminium	+0,0037
Aluminium bronze	+0,001

Lead	+0,00417
Iron	+0,0045
Electron	
Constantan	0,00005
Copper	+0,0043
Manganin	+0,00001
Brass	+0,0015
Molybdenum	+0,0043
Nickel silver	+0,00007
Nickel	+0,0041
Niccolite	+0,00022
Platinum	+0,0039
Platinum-Rhodium (10 % Rh.)	+0,0017
Mercury	+0,00090
Silver	+0,0036
Steel	+0,0045... 0,005
Tantalum	+0,0034
Bismuth	+0,0037
Tungsten	+0,004-1
Zinc	+0,0039
Tin	+0,0042

Table 5 Values of current-carrying capacity and maximum permissible rated current of the overcurrent protection device for lines with copper conductor and plastic, silicone-rubber or glass-silk insulation

Conductor cross-sectional area	Current-carrying capacity				Rated current of overcurrent protection device			
	A				A			
mm^2	1	2	3	4	1	2	3	4
0,5	12	10	9	8	10	10	6	6
0,75	16	13	12	11	16	10	10	10
1,0	20	17	15	14	20	16	10	10
1,5	26	22	20	18	25	20	20	16
2,5	36	31	27	24	36	25	25	20
4	50	43	38	34	50	36	36	25
6	63	54	50	46	63	50	50	36
10	86	74	64	59	80	63	63	50
16	117	101	87	80	100	100	80	80
25	155	133	116	105	125	125	100	100
35	192	165	144	130	160	160	125	125
50	240	206	180	163	224	200	160	160
70	300	259	225	204	300	250	224	200
95	365	314	274	248	355	300	250	224
120	425	366	319	289	425	355	300	250

150	480	413	360	326	425	355	355	300
185	542	466	406	368	500	425	355	355
240	640	551	480	435	600	500	425	425
300	735	633	551	500	600	600	500	500

These values also apply to three-phase four-wire systems with neutral conductor and separate protective conductor (five-wire systems).

Pay attention to the current-carrying capacity factors according to the Tables 9 to 12.

Table 6 Values of current-carrying capacity and maximum permissible rated current of the overcurrent protection device for lines with aluminium conductor and plastic, silicone-rubber and glass-silk insulation

Conductor cross-sectional area	Current-carrying capacity				Rated current of overcurrent protection device			
	A				A			
	for number of cores carrying current in operation							
mm^2	1	2	3	4	1	2	3	4
2,5	27	23	30	18	25	20	20	16
4	37	32	28	24	36	25	25	20
6	50	43	37	34	50	36	36	25
10	67	57	50	46	63	50	50	36
16	90	77	67	61	80	63	63	50

25	120	103	90	81	100	100	80	80
35	148	127	111	100	125	125	100	100
50	187	161	140	127	160	160	125	125
70	231	200	173	154	200	200	160	125
95	282	243	212	191	250	224	200	160
120	328	283	246	223			224	200
150	376	325	283	249	355	300	250	224
185	480	370	322	292	425	355	300	250
240	502	492	376	342	500	425	355	300
300	578	497	433	395	500	425	425	355

Use:

With more than one conductor (core), the current-carrying capacity and the rated current of the overcurrent protection device are reduced as stated above.

The values also apply to three-phase four-wire systems with neutral conductor and separate protective conductor (five-wire systems).

Pay attention to the current-carrying capacity factors according to the tables 9 to 12.

Table 7 Values of current-carrying capacity and maximum permissible rated current of the overcurrent protection device for rubber-insulated lines with copper conductor

Conductor cross-	Current-carrying	Rated current of overcurrent

sectional area	capacity				protection device			
	A				A			
	for number of cores carrying current in operation							
mm^2	1	2	3	4	1	2	3	4
0,5	11	9	9	8	10	6	6	6
0,75	15	12	11	10	10	10	10	10
1	19	16	14	13	16	16	10	10
1,5	24	21	19	17	20	20	16	16
2,5	34	29	25	23	25	25	25	20
4	47	41	36	32	36	36	36	25
6	60	51	47	43	50	50	36	36
10	82	70	61	56	80	63	50	50
16	111	96	83	76	100	80	80	63
25	147	126	110	100	125	125	100	100
35	182	157	137	124	160	125	125	100
50	229	196	171	155	224	160	160	125
70	285	246	214	194	250	224	200	160
95	347	300	260	236	300	300	250	224
120	404	348	303	274	355	300	300	250
150	456	393	342	310	425	355	300	300
185	515	442	385	350	500	425	355	300
240	608	523	456	413	600	500	425	355

300	700	602	523	475	600	600	500	425

Use:

With more then one conductor (core), the current-carrying capacity and the rated current of the overcurrent protection device are reduced as stated above.

The values also apply to three-phase four-wire systems with neutral conductor and separate protective conductor (five-wire systems).

Pay attention to the current-carrying capacity factors according to the Tables 9 to 12.

Table 8

Values of current-carrying capacity and maximum permissible rated current of the overcurrent protection device for rubber-insulated lines with aluminium conductor

Conductor cross-sectional area	Current-carrying capacity				Rated current of overcurrent protection device			
	A				A			
	for number of cores carrying current in operation							
mm2	1	2	3	4	1	2	3	4
2,5	26	22	19	17	25	20	16	16
4	35	30	27	23	25	25	25	20
6	47	41	35	32	36	36	25	25

10	63	54	47	44	63	50	36	36
16	85	73	64	58	80	63	63	50
25	144	98	85	77	100	80	80	63
35	141	121	105	95	125	100	100	80
50	178	153	133	121	160	125	125	100
70	220	190	164	146	200	160	160	125
95	268	231	202	182	250	224	200	160
120	312	269	234	212	300	250	224	200
150	358	309	269	236	355	300	250	224
185	408	351	306	278	355	300	300	250
240	477	410	358	325	425	355	355	300
300	550	472	412	374	500	425	355	355

Use:

With more than one conductor (core), the current-carrying capacity and the rated current of the overcurrent protection device is reduced as sated above.

The values also apply to three-phase four-wire systems with neutral conductor and separate protective conductor (five-wire systems).

Pay attention to the current-carrying capacity factors according to the Tables 9 to 12.

Current-carrying capacity factors

These are factors by which the values of current-carrying capacity given in the Tables 6 to 8 have to be multiplied when special conditions are given.

These conditions may be:

- bundled lines installed freely in air
- bundled lines installed in pipes or conduit subways
- multicore lines with more than 4 conductors (cores)
- multicore lines installed in a piled-up arrangement which are loaded at the same time
- ambient temperatures which deviate from 25° C (298 K) and are higher

If multicore lines are fastened individually by means of spacing clips side by side, the current-carrying capacity factor of 0,9 is applicable irrespective of the number of lines placed side by side.

In the case of ambient temperatures higher than 25° C (298 K), the limiting temperature for the conductor of the line used must be taken into consideration.

There are limiting temperatures of conductors

- **of 60°C (333 K),**
- **of 70°C (343 K) and**
- **of 180°C (453 K).**

If several current-carrying capacity factors are applicable, then the values of current-carrying capacity given in the Tables 6 to 8 must be multiplied by all of the applicable factors.

The rated current of the overcurrent protection device must be specified according to the newly calculated current-carrying capacity when factors of the current-carrying capacity are used.

In this event, the rated current of the overcurrent protection device must be below the value of the newly calculated current-carrying capacity of the line.

Table 9 Current-carrying capacity factors for single-core lines bunched and laid out as open-wire line, in pipe trench or service duct or for multi-core lines with more than 4 cores

Number of lines or cores	Current-carrying capacity factor
2	0,85
3	0,75
4	0,68
5	0,62
6	0,58
7	0,55
8	0,53
9	0,50
10	0,48
15	0,42
20	0,38
25	0,35
30	0,33

35	0,31
40	0,30
45	0,29
50	0,28

Table 10 Current-carrying capacity factors for bunched multi-core lines

Number of multi-core lines	Current-carrying capacity factors in case of		
	open-air bunching	direct side-by side arrangement on walls or ceilings	bunching in pipe trench or service duct
2	0,89	0,83	0,81
3	0,80	0,76	0,75
4	0,73	0,73	0,69
5	0,69	0,71	0,65
6	0,66	0,70	0,62
7	0,63	0,69	0,60
8	0,61	0,69	0,58
9	0,59	0,68	0,56
10	0,57	0,68	0,55
15	0,50	0,66	0,49
20	0,47	0,64	0,46

25	0,44	0,62	0,43
30	0,42	0,60	0,41
35	0,40	0,59	0,40
40	0,39	0,58	0,39

Table 11 Factors of current-carrying capacity in dependence of constant ambient temperatures for lines with a conductor limiting temperature in continuous operation of 60° C (333 K) and 70° C (343 K)

Ambient temperature		Current-carrying with a conductor capacity factors for lines limiting temperature of		
°C	**(K)**	**60°C (333 K)**		**70°C (343 K)**
5	(278)		1,25	
10	(283)		1,19	
15	(288)		1,13	
20	(293)		1,07	
25	(298)		1,00	
30	(303)	0,92		0,94
35	(308)	0,83		0,87
40	(313)	0,74		0,80
45	(318)	0,63		0,72
50	(323)	0,51		0,64
55	(328)	0,36		0,55
60	(333)			0,46

60	(333)	-		0,46
65	(338)	-		0,37

Table 12 Factors of current-carrying capacity in dependence of constant ambient temperatures for lines with a conductor limiting temperature of 180°C

Ambient temperature		Current-carrying capacity factor	Ambient temperature		Current-carrying capacity factor
°C	**(K)**		**°C**	**(K)**	
55	(328)	1,00	120	(393)	0,69
60	(333)	0,98	130	(403)	0,63
70	(343)	0,94	140	(413)	0,56
80	(353)	0,90	150	(423)	0,49
90	(363)	0,85	160	(433)	0,40
100	(373)	0,80	170	(443)	0,28
110	(383)	0,75	175	(448)	0,20

Example:

A seven-core plastic-insulated line with copper conductor o and a conductor rated cross-sectional area of 1,5 mm is to be installed at a constant ambient temperature of 35°C (308 K). What is the current-carrying capacity of the line with a conductor limiting temperature of 70°C (343 K)?

Solution:

According to Table 5, the current-carrying capacity of one core is 26 A.

For 7 cores, the factor of current-carrying capacity is 0,55; at a constant ambient temperature of 35°G (308 K) the factor of current-carrying capacity is 0,87 (conductor limiting temperature 70°C or 343 K) according to Table 10.

Actual current-carrying capacity

26 A • 0,55 • 0,87 = 12 A.

Rated current for the overcurrent protection device is 10 A.

Table 13 Limiting temperature for conductors

Type of cable	**Conductor limiting temperature**			
	°C	**(K)**		
	continuously		**at short-circuit**	
1-kV plastic cable	70	(343)	180	(453)
10-,20-,30-kV plastic cable	70	(343)	200	(473)
1-kV solid-type cable	80	(353)	200	(473)
10-kV solid-type cable	55	(328)	165	(438)
20-kV solid-type cable	55	(328)	145	(418)
30-kV solid-type cable	45	(318)	130	(408)

When selecting cables with respect to their current-carrying capacity, the following factors must be taken into consideration:

- The thermal resistance of the soil; it is dependent on the type of soil and the moisture content of the soil.

- Loaded cables, heating lines and the like installed in close vicinity.

- Heat retention due to air cushions, protective covers, in ducts, pipes or nests of tubes.

Table 14 Current-carrying capacity of 1-kV solid-type cables for individual installation, with reduced solid sheath and fully saturated impregnation

Rated cross-sectional area of conductor	Single -core cables		Two-core cables		Three-core and four-core cables	
mm^2	Cu	Al	Cu	Al	Cu	Al
1,5	-	-	30	-	25	-
2,5	-	-	35	30	30	25
4	-	-	45	35	40	30
6	-	-	60	45	55	40
10	-	-	85	65	75	60
25	-	-	145	115	125	100
50	285	230	215	175	185	150
70	350	280	260	210	225	180
120	495	395	350	280	315	250
185	630	510	450	360	410	330

240	740	590	525	420	475	380
300	840	675	590	470	545	435
400	1000	800	700	565	645	515
500	1140	910	-	-	-	-
1000	1740	1390	-	-	-	-

Table 15 Current-carrying capacity of three unarmoured single-core solid-type cables with lead sheath, fully impregnated, in three-phase systems, separately lying side by side

Nominal cross-section of the conductor	**1 kV**	
	Current - carrying capacity in A	
mm^2	**Cu**	**Al**
50	250	200
70	300	240
120	410	330
185	510	405
240	575	460
300	640	510
400	725	580
500	790	630
1000	950	805

The values of Table 15 are applicable to cables lying side by side in a clearance of about 7 cm, in consideration of the metallic sheath losses in case of cable sheaths short-circuited at both cable ends.

The current-carrying capacity of three unarmoured single-core cables with A1-sheath separately lying side by side amounts to 90 % of the values according to Table 15.

Table 16 Current-carrying capacity of three unarmoured single-core solid-type cables with lead sheath, non-draining, in three-phase systems, separately lying side by side

Nominal cross-section of the conductor	**1 kV**	
mm^2	**Current-carrying capacity in A**	
	Cu	**Al**
50	250	200
70	300	240
120	410	330
185	510	405
240	575	460
300	640	510
400	725	580
500	790	630
1000	950	805

The values of Table 16 are applicable to cables lying side by side in a clearance of about 7 cm, in consideration of the metallic sheath losses in case of cable sheaths

short-circuited at both cable ends.

The current-carrying capacity of three unarmoured single-core non-draining cables with Al-sheath separately lying side by side amounts to 90 % of the values according to Table 16.

The current-carrying capacity of three touching single-core non-draining cables with Al-sheath arranged in a triangle amounts to 105 % of the values according to Table 16.

Table 17 Current-carrying capacity of 1-kV-plastic cables

Nominal cross-section of the conductor	Single-core cables		Two-core cables		Three- and four-core cables	
	Current-carrying capacity				in A	
mm^2	Cu	Al	Cu	Al	Cu	Al
1,5	-	-	25	-	20	-
2,5	-	-	30	25	25	20
4	-	-	40	50	35	25
6	-	-	55	40	45	35
10	-	-	75	55	65	50
25	-	-	120	95	110	90
50	260	210	-	-	165	125
70	315	250	-	-	200	155
120	445	360	-	-	285	220

185	570	455	-	-	370	285
240	665	530	-	-	430	335
300	755	605	-	-	-	-
400	880	720	-	-	-	-
500	990	800	-	-	-	-

The carrying capacity specified in the Tables 14...17 is to be reduced to the following specified percentages in case of deviations from the mentioned conditions of installation.

Table 18 Reduction in case of bunched multi-core cables in three-phase systems and cables in direct current systems

Number of cables in the trench		**2**	**3**	**4**	**5**	**6**	**8**	**10**
Carrying capacity in	%	90	80	75	70	65	62	60

The carrying capacity of cables under protective hoods diminishes to 90 % of the values found out in application of other reductions (see Tables 18...25).

The reductions are applicable to cables lying side by side in a clearance of about 7 cm.

Table 19 Reduction in case of bunched single-core cables in three-phase systems

Number of systems in the trench	**2**	**3**	**4**
Carrying capacity in %	80	75	70

The reductions are applicable to single-core cables lying side by side in a clearance of about 7 cm.

The values of the Tables 20 and 21 are applicable to cables in unarmoured cement pipes in the earth with a clear interior diameter of about 150 mm and 20 mm wall thickness in an horizontal arrangement with reciprocal touch and an outer diameter of 50 mm.

Table 20 Reduction in case of multi-core cables and single-wire cables in single pipes bunched in a triangle

Number of pipes	1	2	3	4	5	6	7	8	9	10
Carrying capacity of the cables in %	80	72	68	65	63	61	60	59	58	57

Table 21 Reduction, in case of single-core cables in single pipes in three-phase systems

Number of pipes	3	6	9
Number of systems	1	2	3
Carrying capacity of the cables in %	85	76	72

Table 22 Reduction in case of bunched cables in the open air

Cable distance	Carrying capacity in %	
	3 cables or 3 cable systems	**6 cables or 6 cables systems**
Space between the cables is equal to the	93	87

cable diameter	[illegible]	[illegible]
No space between the cables (reciprocal touch)	81	74

Table 23 Reduction in case of an ambient temperature for plastic cables deviating from 20°C

Rated voltage	**Carrying capacity in % in case of an ambient temperature of °C**							
kV	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	115	110	105	100	95	89	84	77

<u>Example of calculation:</u>

For the transmission of 1,25 MVA with an operating voltage of 6 kV three-phase current a cable is required. This cable is to be hung by means of an auxiliary cable side by side with two cables hanging already in a shaft. The space between the cables is equal to the cable diameter. The ambient temperature is 30°C.

<u>Solution:</u>

$$I = \frac{P}{U \cdot \sqrt{3}} = \frac{1250000VA}{6000V \cdot \sqrt{3}} \approx 120A$$

A three-core cable with screened cores and with non-draining, intensified insulation is to be chosen.

Table 24 Reduction in case of an ambient temperature for solid-type cables deviating;

from 20 %

Rated voltage kV	Carrying capacity in % in case of an ambient temperature of °C							
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	112	108	104	100	96	91	87	82
10,20	120	113	107	100	93	85	76	65
30	126	118	110	100	90	78	63	45

Occuring factors of reduction:

- 93 % for laying three cables side by side (space between the cables = cable diameter, see Table 22).

- 85 % for raised ambient temperature of 30 % (see Table 23).

Total reduction factor = 0,93 · 0,85 ≈ 0,79

Table 25 Continuous carrying capacity of the most important overhead-line materials for an over temperature of 40°C

Cable cross section	Copper	Pure aluminium	Aldrey	Steel-aluminium	
				1:6	**1:4**
mm^2	**A**	**A**	**A**	**A**	**A**
16	115	92	88	-	-
25	151	121	115	-	-
35	174	149	142	145	225

35	174	149	142	145	225
50[1]	234	187	178	170	300
50[2]	231	185	176	-	-
70	282	226	215	235	355
95	357	283	269	290	440
120	411	329	313	345	505
150	477	382	363	400	560
185	544	435	414	455	650
240[3]	630	502	479	-	-
240[4]	641	513	488	530	770
300	747	598	568	615	-

1) 7-wire (1 layer)
2) 19-wire (2 layers)
3) 37-wire (3 layers)
4) 61-wire (4 layers)

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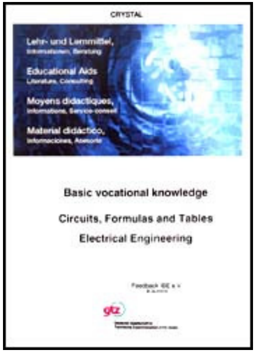

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11. Basic symbols and formulas of electrical engineering

The following is valid:

I = current intensity in A
E = empressed voltage in V
U = voltage, terminal voltage in V
R = resistance in ω
L = inductivity in H $1\text{H} = 1\frac{\text{V}_\text{S}}{\text{A}}$

ω = gyro-frequency in $\frac{1}{\text{S}}$ or Hz

f 1

= frequency in $\frac{1}{S}$ or Hz

C = capacity in F $1F = 1\frac{As}{V}$

ρ = resistivity in $\frac{\Omega \cdot mm^2}{m}$

χ = unit conductance in $\frac{m}{\Omega \cdot mm^2}$

A = conductor cross-section in mm^2

d = diameter in mm

P = power in W (active power)

Q = reactive power in Var

S = apparent power in VA

W = work in Wh or Ws

cos φ = power factor

η = efficiency

Θ = flux in A

B = magnetic induction in T or $\frac{VS}{m^2}$ or $\frac{Wb}{m^2}$

H

A

E	= magnetic field strength i $\frac{V}{n}$	
	= electric field strength in $\frac{V}{m}$	
ϕ	= magnetic flux in Wb or Vs	
F	= force in N	$1N\frac{kg \cdot m}{s^2}$
v	= velocity in $\frac{m}{s}$	
w	= number of turns	
t	= time in s or h	
ϑ K	= initial temperature	
ϑ W	= final temperature	
R_K	= resistance at initial temperature	
R_W	= resistance at final temperature	
$\propto$	= temperature coefficient in $\frac{1}{grd}$	
π	= 3,14	

influence of the temperature on the resistance of the conductor $R_W = R_K \cdot [1 + \alpha(\vartheta_2 - \vartheta_1)]$

11.1. General direct current engineering

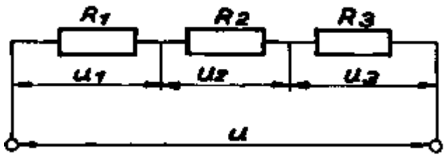
Ohm's Law

$U [V$ $]$

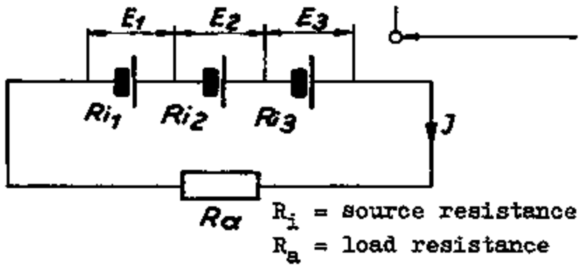
	$I = \frac{U}{R}$	$\left[\frac{V}{\Omega} = A\right]$
power	$P = U_2 \cdot I$	[W]
	$P = I^2 \cdot R$	[W]
	$P = \frac{U^2}{R}$	[W]
work	$W = U \cdot I \cdot t$	$[V \cdot A \cdot s = Ws]$
	$W = P \cdot t$	$[W \cdot s = Ws]$
diameter of a conductor	$A = \frac{\pi d^2}{4}$	$[mm^2]$
resistance of a conductor	$R = \frac{\ell : 1}{A}$	$[\Omega]$
	$R = \frac{1}{\chi \cdot A}$	$[\Omega]$
influence of temperature on the resistance of the conductor	$R_W = R_K$	$[1 + \propto(\vartheta_2 - \vartheta_1)]$

Connection of resistances and power sources

- **series connection**



Figure



Figure

$R_G = R_1 + R_2 + R_3$ (total resistance)

$U = U_1 + U_2 + U_3$.....

$E_G = E_1 + E_2 + E_3$

$I = \frac{E_G}{\sum R_1 + R_a}$ condition: $R_{i1} = R_{i2} = R_{i3}$

$U = I \cdot R_a$

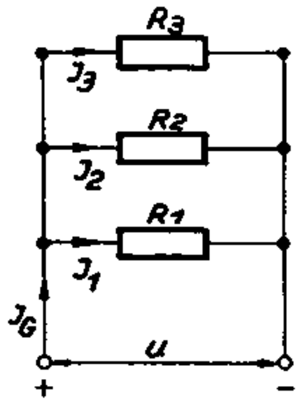
2. Kirchhoff's Law

The sum of all voltages around a closed path in an electrical system is zero.

$$\sum E = \sum I \cdot R$$

The sum of the impressed voltage is equal to the sum of the voltage drops.

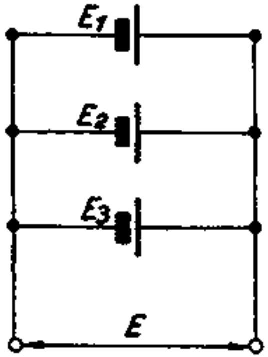
- **parallel connection**



R_E = equivalent resistance

I_G = total current intensity

Figure



Figure

R_E = equivalent resistance

I_G = total current intensity

$$\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

Condition:

Equal power sources are connected in parallel.

$E = E_1 = E_2 = E_3$

for 2 resistances connected $$R_E = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

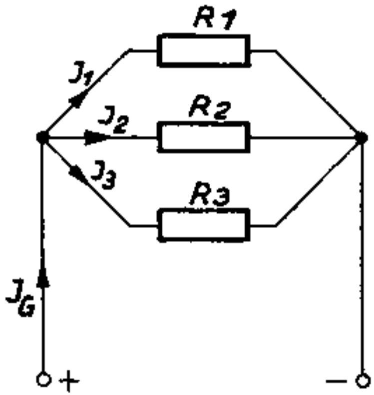
for n equal resistances $$R_E = \frac{R}{n}$$

$I_G = I_1 + I_2 + I_3$

1. Kirchhoff’s Law

At each junction the sum of the currents flowing toward the junction is equal to the sum of the currents flowing away from the junction.

$$I_G - I_1 - I_2 - I_3 = 0$$



Figure

11.2. Magnetic field

flux: $\Theta = I \cdot w\,[A]$

magnetic flux: $\Phi = \dfrac{\Theta}{R_m}\,[\mathrm{Vs}]$

magnetic resistance:

magnetic resistance: $R_m = \frac{1}{\mu \cdot A}\left[\frac{1}{H}\right]$

1 = magnetically effective length in m

A = flux passage area in m^2

R_m in $\frac{1}{\mathrm{H}}$

comparative figure u_r for air = 1, 000 000 4

magnetic permeability $\mu = \mu_o \cdot \mu_r$

relative permeability μ_r - comparative figure

induction constant $\mu_o = 1.256 \cdot 10^{-6}\left[\frac{Vs}{Am}\right]$

magnetic field strength $\Theta = \frac{\Theta}{1} = \frac{I \cdot w}{1}\left[\frac{A}{m}\right]$

magnetic induction $B = \mu \cdot H = \mu_o \cdot \mu_r \cdot H$

$$B = \frac{\Phi}{A}\left[\frac{Vs}{m^2}\right]$$

11.3. Law of induction

induced voltage $E = -w \cdot \frac{\Delta\Phi}{\Delta t}$ [V]

self-induction
- self-inductance [H]

w^2

$$L = \frac{w \cdot \Phi}{I}$$ [H]

- voltage of the self-induction $E_s = -L\frac{\Delta I}{\Delta t}$ [V]

11.4. Electric field

electric field strength $EE = \frac{U}{I}$ $\left[\frac{V}{m}\right]$

= voltage in V

= thickness of the dielectric in m

charge Q = I · t [As]

capacity $C = \frac{Q}{U}$ [F]

Q = quantity of electricity in As

C in F (1F = 1 As/V)

equation of dimensioning $C = \varepsilon\frac{A}{l}$

dielectric constant $\varepsilon = \varepsilon_0 \cdot \varepsilon_r$

relative dielectric constant ε_r: matter constant, relative to the vacuum

absolute dielectric constant $\varepsilon_r : 8{,}86 \cdot 10^{-14} \frac{F}{cm}$

dielectric flux density D = ε ▪ E

11.5. Alternating current engineering

frequency $f = \frac{1}{T}$

T = cycle duration in s

gyro-frequency $\omega = \frac{2\pi}{T} = 2\,\pi\,f$

phase angle $\varsigma = \omega_t$

instantaneous value of a sinusoidal a.c. voltage $u = U_{max} \sin(\omega t + \zeta)$

instantaneous value of a sinusoidal a.c. current $i = I_{max} \sin(\omega t + \zeta)$

maximum value

- of a sine-wave voltage $U_{max} = U \cdot \sqrt{2}$

U = virtual value

- of a sine current $I_{max} = I \cdot \sqrt{2}$

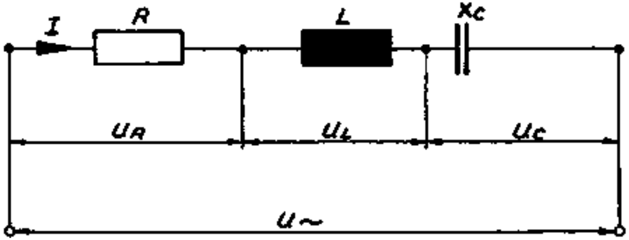
I = virtual value

inductive resistance $X_L = \omega L\,[\Omega]$

(inductive reactance) L in H

capacitive resistance $X_C = \frac{1}{\omega C} [\Omega]$

(capacitive reactance) C = capacity in F



Series connection

impedance $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ [Ω]

ohmic drop in voltage $U_R = I \cdot R$ [V]

inductive voltage drop $U_L = I \cdot X_L = I \cdot \omega L$ [V]

capacitive voltage drop $U_C = I \cdot x_C = I \cdot \frac{1}{\omega C}$ [V]

Ohm's law for alternating current $I = \frac{U}{Z} = \frac{U}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$ [A]

Powers in case of single-phase alternating current

apparent power $S = U \cdot I$ [VA]

active power $P = U \cdot I \cdot \cos \zeta$ [W]

reactive power $Q = U \cdot I \cdot \sin \zeta$ [Var]

power factor $\cos\zeta = \frac{P}{S}$

Powers in case of three-phase alternating current

apparent power $S = \sqrt{3} \cdot U \cdot I$ [VA]

active power $P = \sqrt{3} \cdot U \cdot I \cdot \cos\zeta$ [W]

reactive power $Q = \sqrt{3} \cdot U \cdot I \cdot \sin\zeta$ [Var]

power factor $\cos\zeta = \frac{P}{S}$

efficiency for motors and generators $\eta = \frac{P_e}{P_i}$

P_e = effective power

P_i = indicated power

speed calculation of three-phase motors rotating field speed $n_D = \frac{60\,\mathrm{f}}{\mathrm{P}}$ $\left[\frac{1}{\mathrm{min}}\right]$

p = number of pole pairs

slip $$s = \frac{n_o - n}{n_D} \cdot 100$$ [%]

n = rotor speed

11.6. Calculation of power

calculation of power losses

P_V = power loss in per cent

direct current

$$P_V = \frac{200 \cdot 1 \cdot P_2}{\chi \cdot A \cdot U}$$ [%]

single-phase alternating current

$$P_V = \frac{200 \cdot 1 \cdot P_2}{\chi \cdot A \cdot U \cdot \cos^2 \zeta}$$ [%]

three-phase alternating current

$$P_V = \frac{100 \cdot 1 \cdot P}{\chi \cdot A \cdot U^2 \cdot \cos^2 \zeta}$$ [%]

$21 \cdot I$ [V]; $21 \cdot P$ [V]

$U_V = \frac{[illegible]}{\chi \cdot A}$ [V]; $U_V = \frac{[illegible]}{\chi \cdot 17 \cdot U}$ [V]

$U_V = \frac{21 \cdot I \cdot \cos\zeta}{\chi \cdot A}$ [V]; $U_V = \frac{21 \cdot P}{\chi \cdot A \cdot U}$ [V]

$U_V = \frac{\sqrt{3} \cdot 1 \cdot I \cdot \cos\zeta}{\chi \cdot A}$ [V]; $U_V = \frac{1 \cdot P}{\chi \cdot A \cdot U}$ [V]

Determination of a conductor cross-section

- Calculation of the rated current from current, voltage and power factor.

- Division by all suitable current-carrying capacity factors of the Tables 9 to 12.

- Determination of the conductor cross-section according to the given current-carrying capacity factors after the calculated fictive current.

- Calculation of the conductor cross-sections according to the given power and voltage loss.

- Comparison of the cross-sections found out under the third and fourth point. The greatest is chosen as the cross-section to be installed.

Conversion of the measuring units of work and power

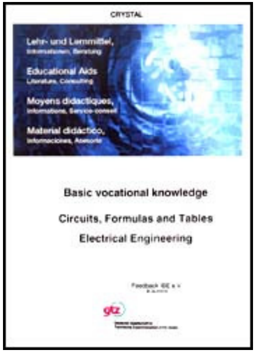
Work

J	erg	kpm	kWh	PSh	kcal
1 1	10^7	0.102	$0.278 \cdot 10^{-6}$	$0.378 \cdot 10^{-6}$	$0.239 \cdot 10^{-3}$

			$0.278 \cdot 10^{[illegible]}$	$0.378 \cdot 10^{[illegible]}$	$0.239 \cdot 10^{[illegible]}$
10^{7}	1	$0.102 \cdot 10^{-7}$	$0.278 \cdot 10^{-13}$	$0.378 \cdot 10^{-13}$	$0.239 \cdot 10^{-10}$
9.81	$9.81 \cdot 10^{7}$	1	$2.72 \cdot 10^{-6}$	$3.70 \cdot 10^{-6}$	$2.34 \cdot 10^{-3}$
$3.60 \cdot 10^{6}$	$3.60 \cdot 10^{13}$	$3.67 \cdot 10^{5}$	1	1.36	860
$2.65 \cdot 10^{6}$	$2.65 \cdot 10^{13}$	$2.70 \cdot 10^{5}$	0.7355	1	632
4187	$4.19 \cdot 10^{10}$	427	$1.16 \cdot 10^{-3}$	$1.58 \cdot 10^{-3}$	1

Power

W	kW	kpm s^{-1}	PS	kcal s^{-1}	kcal h^{-1}
1	10^{-3}	0.102	$1.36 \cdot 10^{-3}$	$2.39 \cdot 10^{-4}$	0.86
10^{3}	1	102	1.36	0.239	860
9.81	$9.81 \cdot 10^{-3}$	1	0.0133	$2.34 \cdot 10^{-3}$	8.43
735.5	0.7355	75	1	0.1757	632
4187	4.19	427	5.69	1	3600
1.16	$1.16 \cdot 10^{-3}$	0.119	$1.58 \cdot 10^{-3}$	$2.78 \cdot 10^{-4}$	1



Preface

This Textbook is intended for all trainees in the field of electrotechnology. It contains the more important circuit diagrams and formulas and a limited number of selected tables of direct-current and alternating-current engineering.

With the help of this Textbook, the trainee will be in a position to read and interpret electrical wiring and circuit diagrams in order to perform his job according to the rules of good workmanship. At the same time, the trainee is encouraged to prepare

and draw circuit diagrams without assistance and to use graphical symbols correctly.

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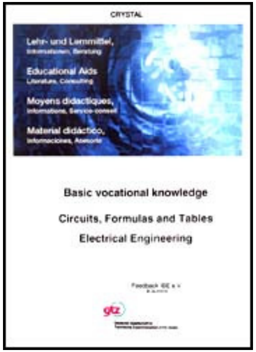

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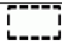
1. Selected Graphical Symbols of Electrotechnology

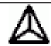
1.1. Graphical Symbols for General Circuit Elements

Term	Graphical Symbol	
	in full	simplified
Polarity		
positive	+	
negative	-	
centre point, neutral	N	
Directions of transmission and motion		
energy direction	⇄	
direction of motion	⇄	
sense of rotation (rotating)		
direction of turning		
Possibilities of adjusting, setting		

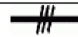
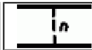
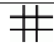
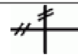
Possibilities of adjusting, setting		
adjusting		
setting		
Variabilities		
general, linear		
non-linear		
Pulse shapes		
rectangular pulse, positive		
rectangular pulse, negative		
Shieldings		
general		
electrostatic		
electromagnetic		
shielding of a component		

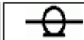
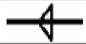
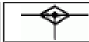
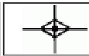
1.2. Graphical Symbols for Types of Current, Voltage and Connections

Term	**Graphical Symbol**	
	in full	**simplified**
Type of voltage and current		
direct voltage		
direct current		

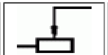
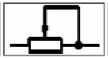
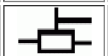
alternating voltage, alternating current		
alternating voltage within the range of audio frequency		
alternating voltage within the range of high frequency		
direct or alternating voltage		
Alternating current connections		
star connection		
delta connection		
star-delta connection		
zig-zag connection		

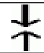
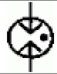
1.3. Graphical Symbols for Lines and Line Connections

Term	**Graphical Symbol**	
	in full	**simplified**
Lines		
line, general		
2 lines		
3 lines		
4 lines		
n - lines		
crossing of two lines without connection		
crossing of two lines with connection		

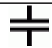
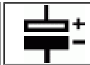
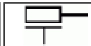
crossing of two lines with connection		
shielded line		
coaxial line		
Line and cable connections		
earth connection		
ground connection (chassis or the like)		
disconnectable and non-disconnectable electrical connection, general		
disconnectable electrical connection, e.g. terminal		
cable termination		
coupling sleeve		
joint box for a branching		
joint box for two branchings		

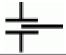
1.4. Graphical Symbols for Resistors

Term	Graphical Symbol	
	in full	simplified
resistor, general		
resistor, variable, with possible circuit interruption		
resistor, variable, without circuit interruption		
resistor as voltage divider		
resistor, adjustable		

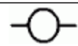
resistor, infinitely variable resistor, voltage-dependent non-linear		
fusible cut-out, general		
potential fuse, general		
two-electrode arrester		
ion arrester (dot = gas filing)		

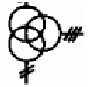
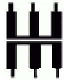
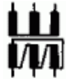
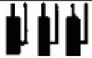
1.5. Graphical Symbols for Capacitors

Term	Graphical Symbol	
	in full	simplified
capacitor, general		
electrolyte capacitors		
polarised		
non-polarised		
lead-in capacitor, polarised		
lead-in capacitor, non-polarised		
variable capacitor		
variable capacitor with indication of rotor		

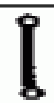
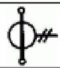
anti-interference capacitor		

1.6. Graphical Symbols for Coils and Transformers

Term	Graphical Symbol	
	in full	**simplified**
Coils		
general		
	or 	
air-cored coil		
	or 	
air-cored coil with two tappings	 or 	
iron core		
iron core and air gap		
iron dust core		
iron-core choke	or 	
Transformers		
single-phase transformer with iron core (if errors cannot be made, the core need not be drawn)		
single-phase transformer with iron core and 3 windings (core not		

single-phase transformer with iron-core and 3 windings (core not represented)		
three-phase transformer in star-star connection (core not represented)		
three-phase transformer, star-delta connection		
three-phase autotransformer in star connection		

1.7. Graphical Symbols for Current and Voltage Transformers

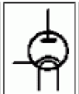
Term	Graphical Symbol	
	in full	simplified
Current transformers		
primary winding	 or 	
secondary winding	 or 	
current transformer, general	 	
Voltage transformers		

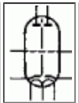
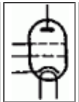
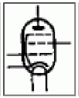
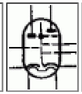
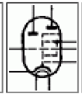
general	 or 	
capacitive	 or 	

1.8. Graphical Symbols for Electrochemical and Electrothermal Sources

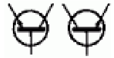
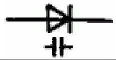
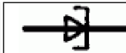
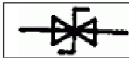
Term	Graphical Symbol	
	in full	**simplified**
battery cell, general		
battery, 5 cells with one tapping		
thermoelectric element		

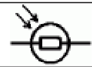
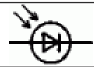
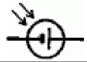
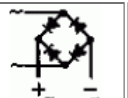
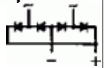
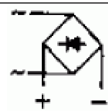
1.9. Graphical Symbols for Tubes

Term	Graphical Symbol	
	in full	**simplified**
diode, indirectly heated		
duodiode, indirectly heated	or	

	 	
triode, indirectly heated	or  	
duotriode with separated cathodes, indirectly heated, heating filament with central tapping, internal screening of the system		
tetrode		
pentode, suppressor grid connected with cathode		
triode - pentode		
triode - heptode (according to the circuit, the systems may be drawn left-and-right reversed)		

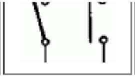
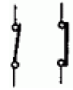
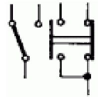
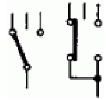
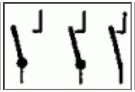
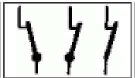
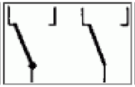
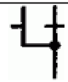
1.10. Graphical Symbols for Semiconductors

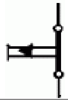
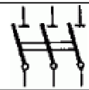
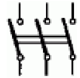
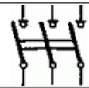
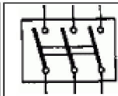
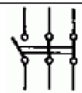
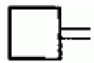
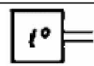
Term	Graphical Symbol	
	in full	simplified
Transistors		
point contact transistor or junction transistor, type p-n-p		
n-p-n transistor		
Semiconductor diodes		
diode with rectifying function	 or 	
capacity diode		
tunnel diode		
avalanche rectifier diode		
avalanche rectifier diode with avalanche effect in both directions		
backward diode		
Thyristors		
general		
backward blocking		
backward conducting		
n-type gate, controlled at anode side		
p-type gate, controlled at cathode side		

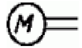
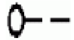
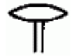
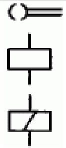
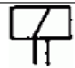
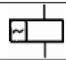
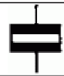
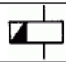
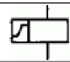
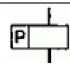
p-type gate, controlled at cathode side		
Semiconductor elements which can be influenced by light		
photoresistance cell		
photodiode		
photocell with depletion layer		
phototriode p-n-p		
switching diode p-n-p-n		
Semiconductor circuits		
switching diode p-n-p-n		
semiconductor valves in bridge connection	 or 	

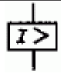
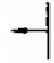
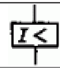
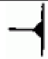
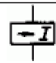
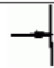
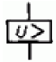
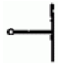
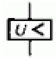
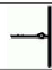
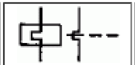
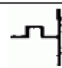
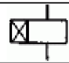
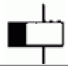
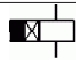
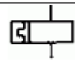
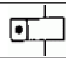
1.11. Graphical Symbols for Switching Devices

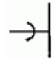
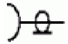
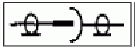
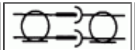
Term	Graphical Symbol	
	in full	simplified
Switching members		
make contacts, general		

make contacts, general		
break contacts, general		
change-over switch, general		
change-over switch with central rest position		
Relay switching members		
make contacts		
break contacts		
change-over switch with interruption in switching		
Switches		
hand-actuated lever switch		
make contacts with automatic resetting		

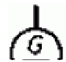
		
break contacts with automatic resetting		
disconnecting switch, three-pole		
power circuit-breaker, three-pole		
power breaker, three-pole		
power switch, three-pole		
switch, three-pole, with one make contact and two break contacts		
Drive members		
drive, general		
drive, thermal		
drive by centrifugal force		

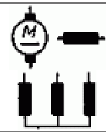
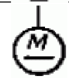
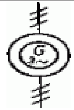
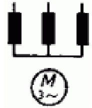
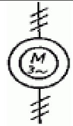
drive by piston		
drive by electrical motor		
drive by cams		
drive by float		
manual drive		
manual drive with automatic resetting		
foot drive		
actuation by means of a key		
drive by relay or contactor		
<u>Electrical drive systems</u>		
relay winding only for alternating current		
winding of a relay insensitive to alternating current		
winding of an electro-thermal relay		
winding of a remanence relay		
winding of a polarised relay		

winding for relay tripping by over-current		
winding for relay tripping by undercurrent		
winding for relay tripping by reverse current		
winding for relay tripping by overvoltage		
winding for relay tripping by undervoltage		
winding for relay tripping by error voltage		
winding for thermal tripping of relay		
relay winding with delay of attraction		
relay winding with delay of dropping		
relay winding with delay of attraction and dropping		
relay winding with electrothermal delay		
relay winding with electronic delay		
winding for relay tripping by open-circuit working		
winding for relay tripping by closed-circuit working		

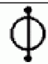
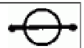
winding for relay tripping by closed circuit working		
winding for relay tripping by overcurrent with time lag		
Plugged connections		
receptacle		
plug		
connector, single-pole		
connector, four-pole		
h.f. coaxial receptacle		
h.f. coaxial connector		
h.f. coaxial connector, two - core		

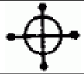
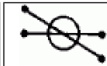
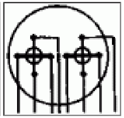
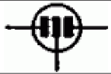
1.12. Graphical Symbols for Machines

Term	Graphical Symbol	
	in full	**simplified**
rotor with winding, commutator and brushes		
asynchronous machine, stator in delta connection, rotor in star connection		
direct-current generator		

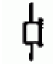
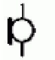
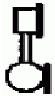
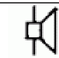
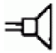
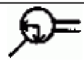
direct-current motor		
three-phase generator		
three-phase motor (cage rotor)		
three-phase motor (slip-ring rotor)		

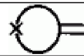
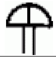
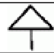
1.13. Graphical Symbols for Meter Movements and Measuring Instruments

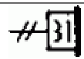
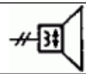
Term	Graphical Symbol	
	in full	**simplified**
voltage path of a movement	 or 	
current path of a movement	 or 	

movement of a wattmeter		
voltage paths for summation or differentiation		
current paths for summation or differentiation		
movement of a two-phase wattmeter with 2 elements		
movement of an ohmmeter		
movement of a frequency meter		
Measuring instruments		
voltmeter		
ammeter		
wattmeter with 2 elements		
electrometer		

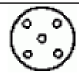
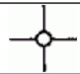
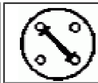
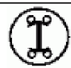
1.14. Graphical Symbols of Electroacoustics

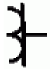
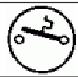
Term	Graphical Symbol	
	in full	simplified
Devices		
telephone receiver		 or 
microphone		 or 
throat microphone		
hand set		
loudspeaker		 or 
monohead, general		
stereohead, general		
record head, mechanical		
replay head, mechanical		
magnetic head, general		

magnetic head, general		
recording head		
playback head		
magnetic head for recording and playback		
erasing head		
bell, general		
alternating current bell		
direct current bell		
single-stroke bell		
buzzer		
horn		
siren		
howler		
Signs		
electromagnetic		
electrodynamic by coil		
electrodynamic by band		
piezoelectric		
magnetostrictive		

capacitive		
carbon		
Examples		
electromagnetic telephone receiver		
carbon microphone		
capacitor microphone		
magnetostrictive loudspeaker		

1.15. Graphical Symbols for Wiring Plans

Term	Graphical Symbol	
	in full	simplified
distribution box		
cut-out, single-pole		
cut-out, two-pole		
cut-out, three-pole		
group switch, single-pole		

multi-circuit switch, single-pole		
single-pole double-throw switch		
four-way switch, single-pole		
plug socket, single		
plug socket, double		
plug socket with protective contact, single		
plug socket with protective contact, double		
luminous key switch		
glow lamp		
fluorescent lamp		
glow igniter		
door opener